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TECHNICAL BACKGROUND INFORMATION FOR THE ORNL ENVIRONMENTAL AND SAFETY REPORT

Volume 2

A Description of the Aquatic Ecology of White Oak Creek Watershed and the Clinch River below Melton Hill Dam

J. M. Loar
J. A. Solomon
G. F. Cada

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1852

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Volumes in the Series of Technical Background Documents
for the ORNL Environmental and Safety Report

Volume No.	Title	Report No.	Authors
1	Radiological Assessment of Residences in the Oak Ridge Area	ORNL/TM-7392/V1	F. S. Tsakeres, K. E. Shank, M. Y. Chaudhry, S. Ahmad, P. M. Dizillo-Benoit, and T. W. Oakes
2	A Description of the Aquatic Ecology of White Oak Creek Watershed and the Clinch River below Melton Hill Dam	ORNL/TM-7509/V2	J. M. Loar, J. A. Solomon, and G. F. Cada

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CONTENTS

LIST OF TABLES

Page

Page

LIST OF FIGURES

Page

Page

ABSTRACT

In order to characterize the aquatic communities in the vicinity of Oak Ridge National Laboratory (ORNL), a biological sampling program was initiated in March 1979 and continued until June 1980. The periphyton, benthic macroinvertebrate, and fish communities were sampled at four sites in White Oak Creek watershed above White Oak Lake. In addition to these communities, phytoplankton, zooplankton, and ichthyoplankton were routinely collected at sites in White Oak Lake, White Oak Creek embayment below the dam, and in the Clinch River above and below the confluence with White Oak Creek. Also, muscle tissue of several fish species, including sauger and striped bass from the Clinch River, was analyzed for seven trace elements (Cd, Cr, Cu, Pb, Hg, Ni, and Zn). The information obtained during this study, which was the first comprehensive survey conducted since the initial one in 1950-53, will be the basis for evaluating the effects of plant operation on aquatic biota in the Environmental and Safety Report for ORNL.

Data on the taxonomic composition, abundance, and temporal distribution of each community are presented for each of three study areas: upper White Oak Creek watershed, White Oak Lake, and the Clinch River (including White Oak Creek embayment). The spatial distribution of major taxonomic groups in each area was examined using analysis of variance techniques and dissimilarity indices. Results obtained from this study are compared with those of previous surveys of White Oak Creek when equivalent sampling methodologies were used. Attempts were also made to document changes that have occurred since the 1950-53 survey.

The present survey also provided data on two communities (periphyton and ichthyoplankton) that had not previously been described for the study area. Periphyton abundance (cell counts, biomass, and chlorophyll a) was substantially higher at the sites below ORNL than at the upstream control station. Weekly sampling of ichthyoplankton indicated high densities of clupeid and *Lepomis* larvae in White Oak Lake in May and June. The occurrence of only two cyprinid larvae in samples collected just above the lake suggests that very limited spawning occurs in that reach of White Oak Creek between ORNL and the lake.

Trace element analysis of axial muscle from bluegill indicated elevated levels of mercury in the fish from White Oak Lake ($\bar{x}$ = 0.70 µg/g wet weight) and the embayment below White Oak Dam ($\bar{x}$ = 0.57 µg/g wet weight). Muscle tissue concentrations at these two sites were significantly higher ($p < 0.05$) than the concentrations found in fish collected from the Clinch River upstream and downstream of the mouth of White Oak Creek and from Melton Hill Reservoir. No significant differences between stations were found in the concentrations of other trace elements. The mercury levels in sauger and striped bass were well below the Food and Drug Administration action level of 1.0 µg/g wet weight ($\bar{x}$ = 95 ng/g and 134 ng/g wet weight respectively).

PREFACE

In order to assess the nonradiological environmental impacts resulting from the operation of the Oak Ridge National Laboratory (ORNL), baseline information on the biotic resources in the vicinity of the facility was required. Consequently, a comprehensive biological sampling program was designed, and sampling was initiated in March 1979. The importance of obtaining data on the aquatic biota in the White Oak Creek watershed was emphasized at a meeting held in December 1978 between representatives from ORNL and various state and federal agencies. In accordance with regulations recently promulgated by the Council on Environmental Quality, this scoping meeting was held for the purpose of identifying issues prior to the preparation of the Environmental and Safety Report (ESR) for ORNL. The data collected during the ORNL biological sampling program, which are presented in this report, will provide the information required to characterize and evaluate the impacts of ORNL operations on aquatic biota in the White Oak Creek watershed. Such an assessment of environmental impact will be performed in the ESR.

Extensive information exists on the terrestrial flora and fauna of the Oak Ridge-DOE Reservation, including the White Oak Creek watershed (e.g., see Krumholz 1954a; Johnson 1964; Olson, Cristofolini, and Cristofolini 1966; Grigal and Goldstein 1971; Mann and Bierner 1975; Anderson, Mann, and Shugart 1977; Bradburn 1977; Johnson, Schreiber, and Burgess 1979). The occurrence of threatened and endangered species on the reservation and the distribution of plant communities (and the fauna associated with them) have been described by Kitchings and Mann (1976). Because adequate baseline information on terrestrial ecology was already available, a systematic characterization of the terrestrial biota in the vicinity of ORNL (similar to that conducted for aquatic biota) was not performed.

1. INTRODUCTION

The environmental impacts from operation of large research and development facilities, such as the Oak Ridge National Laboratory (ORNL), cannot be assessed without adequate information on the ecological resources in the vicinity of such facilities. As a result of the numerous surveys that have been made of the terrestrial flora and fauna on the Oak Ridge—Department of Energy Reservation, including the White Oak Creek watershed, adequate baseline data on terrestrial ecology already exist (see Preface). Studies of the aquatic biota in the vicinity of ORNL, however, have been limited. Most of these latter studies (e.g., Lackey 1957; Kolehmainen and Nelson 1969; Auerbach et al. 1974) were not comprehensive surveys designed to characterize the aquatic environment (e.g., the composition, abundance, and distribution of biological communities), but rather were investigations of the ecological effects of radioactive effluent discharges to White Oak Lake.

The aquatic biota of the White Oak Creek watershed were first characterized almost 30 years ago by Krumholz (1954a, b, c). This initial survey described the composition and abundance of the plankton, benthic macroinvertebrate, and fish communities and was followed by several other studies of a more limited scope. The protozoan and phytoplankton communities in White Oak Lake were investigated during the summer of 1956 (Lackey 1957), and the composition of the fish community in the lake has been described by Kolehmainen and Nelson (1969) and Auerbach et al. (1974). The nonradiological data collected in all three studies consisted primarily of species lists. Finally, rather limited (but quantitative) sampling was conducted of the phytoplankton and zooplankton communities in White Oak Lake in 1972-73 (A. S. Bradshaw, unpublished data) and of the benthic macroinvertebrate communities at six sites in White Oak Creek in 1974-75 (B. G. Blaylock, unpublished data).

These earlier studies of the flora and fauna of the White Oak Creek watershed were either qualitative, out-of-date, and/or too limited in scope (i.e., insufficient sampling effort) to adequately describe the ecological resources in the vicinity of ORNL. As a result, a comprehensive sampling program was designed and initiated in March 1979 and continued through early June 1980. Efforts focused on characterizing the biological communities at selected sites on White Oak Creek above and below ORNL and on the Clinch River upstream and downstream from the confluence of White Oak Creek. The data collected during this sampling program are presented in this report. This information, together with that presented in other volumes of the ORNL technical background reports, will provide the basis for preparation of the ORNL Environmental and Safety Report at a later date.

2. DESCRIPTION OF STUDY AREA

The White Oak Creek drainage basin is located near the southern boundary of the United States Department of Energy Oak Ridge Reservation and has an area of 16.9 km^2 at its mouth at Clinch River kilometer (CRK) 33.5. Parallel northeast-trending ridges constitute the northern and southern borders of the watershed, and a third ridge (Haw Ridge) bisects the basin and separates Bethel Valley to the north from Melton Valley to the south (Fig. 2.1). Elevations in the watershed range from 226 m above mean sea level (MSL) at the mouth of White Oak Creek to 413 m MSL on Melton Hill at the crest of Copper Ridge, the highest point on the 150-km^2 reservation (McMaster 1963; McMaster and Waller 1965).

The largest tributary of White Oak Creek is Melton Branch, which drains an area of 3.8 km^2 (McMaster 1967). It originates at the eastern end of Melton Valley and joins White Oak Creek approximately 500 m above White Oak Lake (when the lake elevation is 227.1 m MSL). Although most of the Oak Ridge National Laboratory (ORNL) is situated in Bethel Valley, some facilities [e.g., High Flux Isotope Reactor (HFIR), low-level radioactive waste disposal areas] are located in Melton Valley. Both Melton Branch and White Oak Creek receive liquid effluents from ORNL operations and leachates from solid and liquid radioactive waste disposal areas in the drainage basin (Dahlman, Kitchings, and Elwood 1977; Oakes and Shank 1979).

A small highway-fill dam located 1.0 km above the mouth of White Oak Creek impounds the lower portion of the watershed. The small, shallow impoundment (White Oak Lake) created by the dam extends approximately 0.7 km upstream and had a surface area of about 8 ha during most of 1979. Water levels in the creek below the dam are controlled by operation of the Melton Hill Dam at CRK 37.2 and Watts Bar Dam, which is located at Tennessee River kilometer (TRK) 852.6, about 61 km below the confluence of the Clinch and Tennessee rivers. When Watts Bar Reservoir is maintained at or near full pool (approximately April to October) and discharges occur at Melton Hill Dam, the subsequent rise in water level in the Clinch River creates an embayment extending from the mouth of the

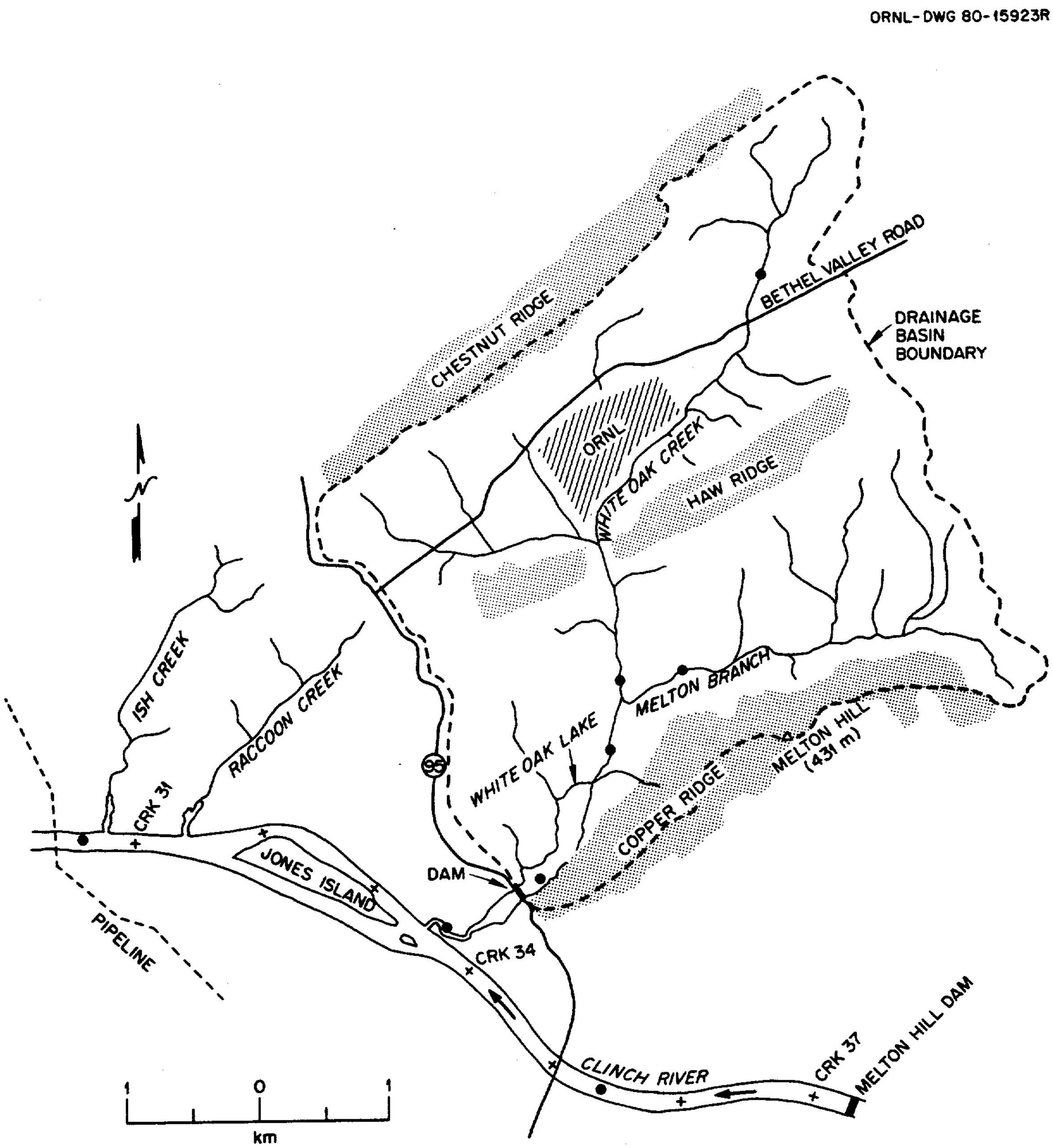

Fig. 2.1. White Oak Creek watershed and Clinch River study areas. Sampling of aquatic biota was conducted at eight sites (•) from March 1979 through early June 1980.

creek to White Oak Dam. Because of this regulated condition, the White Oak Creek watershed is generally considered to be the 15.5-km^2 area (at a lake elevation of 227.1 MSL) above the dam (Edgar 1978). Thus, the study area for the ORNL biological sampling program consisted of four environments: upper White Oak Creek drainage (area above the lake), White Oak Lake, White Oak Creek embayment, and the Clinch River.

2.1 UPPER WHITE OAK CREEK DRAINAGE

The headwaters of White Oak Creek originate on the southeast slope of Chestnut Ridge (Fig. 2.1). The belt of Knox Dolomite underlying the ridge is the principal water-bearing formation, and the springs that occur along the base of Chestnut Ridge and in its valleys are the chief source of the base flow discharge of White Oak Creek (McMaster and Waller 1965). The drainage basin is also underlain by the Rome Formation (Haw Ridge), which is principally composed of siltstone and shale, and the Conasauga Group (Melton Valley), a primarily calcareous shale interlayered with limestone and siltstone (McMaster 1963). Both are poor water-bearing formations (McMaster and Waller 1965). Low-flow measurements have shown that approximately 90% of the flow in the creek originates as groundwater discharge from the Knox Dolomite of Chestnut Ridge, the Chickamauga Limestone of Bethel Valley, and from ORNL plant effluent (McMaster 1967).

Contributions from numerous springs in the headwater region of White Oak Creek [above the sampling station at White Oak Creek kilometer (WOCK) 6.3] provide a thermal environment that is markedly different from that existing below ORNL (Fig. 2.2). For example, on most sampling dates during the summer and early fall, water temperatures at station WOCK 6.3 were 4 to 5°C lower than those at the downstream sites (WOCK 2.1 and 2.7). Thermal discharges from HFIR and the opening in the forest canopy due to the presence of a gravel road which parallels the stream could account for the elevated temperatures in Melton Branch. Initially, the uppermost site on White Oak Creek was also located in an open area, but it later had to be moved about 450 m upstream when the creek went dry, for the second time, in early September. The creek

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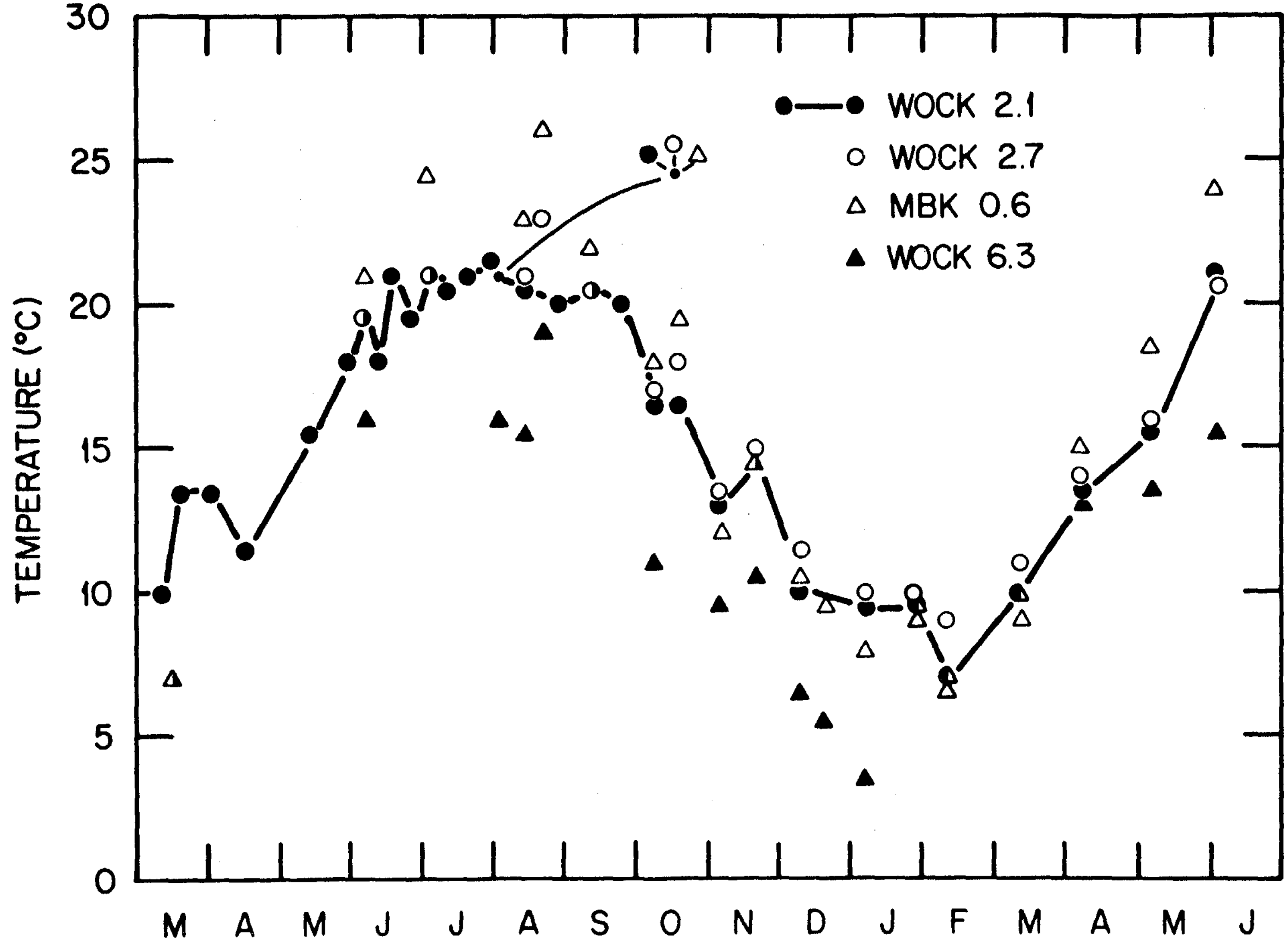

Fig. 2.2. Comparison of surface water temperatures at the four sampling stations in the upper White Oak Creek watershed, March 1979–June 1980. White Oak Dam is located at White Oak Creek kilometer 1.0. With the exception of June 7, 1979 (1225 to 1355 h), and February 11, 1980 (1145 to 1225 h), all data were collected between 0810 and 1115 h. For a given date, all temperature measurements were taken within a 90-min period.

flowed through a shortleaf pine stand at the new location. Both of the downstream stations on White Oak Creek were located in a mixed hardwood forest.

The sampling sites on Melton Branch and White Oak Creek near the headwaters were located on reaches of similar width and depth (Table 2.1). The substrate at both sites consisted primarily of medium (fist-size) to small rubble, with some gravel and sand. Areas of embedded rubble and exposed bedrock were also characteristic of the two areas. Below ORNL, White Oak Creek is wider and deeper, and the substrate consists almost entirely of small rubble and gravel. The stream near all four sampling locations consists of alternating series of pool and riffle areas.

2.2 WHITE OAK LAKE

White Oak Lake is a small, shallow impoundment that functions as a final settling basin for waste effluents discharged to the lake via White Oak Creek, Melton Branch, and other smaller streams. The lake has undergone several significant changes since its impoundment in 1943 (Table 2.2). The water level was lowered in 1953 during the fish population studies of Krumholz (1954c), and in 1955, the lake was drained and the surface area reduced to 2.8 ha (Kolehmainen and Nelson 1969). From 1955 to 1963, thick grasses, herbs, and shrubs covered the former lake bottom (Kolehmainen and Nelson 1969). The size of White Oak Lake varied somewhat over the next 15 years until late November 1979, when the lake level was gradually lowered over a period of several weeks. The elevation was reduced from 227.1 m (745 ft) MSL to 226.2 m (742 ft) MSL (Oakes, Shank, and Kelly et al., in press), resulting in an estimated reduction in surface area of about 5.2 ha.

The water level of the lake is controlled by a vertical sluice gate which remains in a fixed position during normal operations. (The lake level, however, will fluctuate because of storm events or prolonged periods of no rainfall.) Above that elevation, water discharges freely over the top of the gate. Based on flow measurements recorded by the U.S. Geological Survey at White Oak Dam from 1953 to 1955 and from 1960 to 1963 (five water years), the average flow was 0.38 m^3/s or

Table 2.1. Comparison of various physical characteristics of White Oak Creek and Melton Branch at the biological sampling sites shown in Fig. 2.1

All data were recorded concurrently with the collection of biological samples. Location 1 = benthic macroinvertebrate sampling site; Location 2 = periphyton sampling site; N = number of measurements taken

	WOCK 2.1[a]	WOCK 2.7	WOCK 6.3[b]		MBK 0.6[c]
			Lower	Upper	
Temperature (°C)[d]					
Range	7.0-24.0	9.0-24.5	3.5-19.0		6.5-26.5
N	40	22	19		22
Stream width (m)[d]					
Mean	3.8	4.8	1.5	2.7	3.0
Range	3.0-5.1	4.1-6.0	1.2-1.8	2.3-2.9	2.2-3.3
N	9	8	5	4	9
Stream depth (cm)					
Location 1[d]					
Mean	17	19	11	11	11
Range	7-36	8-34	4-20	5-24	6-20
N	27	27	15	12	27
Location 2[e]					
Mean	48	56	36	33	32
Range	33-65	46-69	28-49	25-40	24-43
N	15	16	5	10	16

[a]White Oak Creek kilometer 2.1.

[b]Original sampling site at WOCK 6.3 was abandoned in mid-September because of the dry streambed; the new (upper) site was located about 400 m upstream (WOCK 6.7).

[c]Melton Branch kilometer 0.6.

[d]Data collected during the period March 1979 through February 1980.

[e]Data collected during the period July 1979 through June 1980.

Table 2.2. Historical changes in the surface area of White Oak Lake and the major events associated with significant changes in lake size

N/A = Information not available

Date	Surface area (ha)	Event	Reference
1941		Highway fill raised and concrete culvert installed	Smith (1945) as cited in Krumholz (1954a)
1943	14.5[a]	Vertical sliding gate [top elevation = 228.6 m (750 ft) MSL] installed and spillway closed in October	Krumholz (1954a)
		Generation of radioactive liquid waste at ORNL began and lake served as final settling basin	Clinch River Study Steering Committee (1967)
1945	~12.2	Investigation of structural strength of dam under flood conditions; lake level maintained at 227.5 m (746.5 ft) until June 1948	Oakes, Shank, and Kelly et al. (in press)
June 1948	~10.3	Lake level lowered to 227.2 m (745.3 ft) to facilitate mud sampling. Normal operation from 1948 to 1955 was between elevations 227.7 m (747 ft) and 228.3 m (749 ft).	Oakes, Shank, and Kelly et al. (in press)
April 1953	N/A	Lake partially drained during rotenone survey of fish populations	Krumholz (1954c)
October 1955	2.8[b]	Lake drained; accumulation of radionuclides in lake sediments had come into equilibrium with radioactivity in water, so lake served no useful function in retaining radioactivity but could function as an emergency storage pond in case of accidental release	Clinch River Study Steering Committee (1967)
Summer 1956	0.4	None reported[c]	Lackey (1957)

Table 2.2 (continued)

Date	Surface area (ha)	Event	Reference
1959	N/A	Gate structure renovated to prevent inflow of backwaters from Clinch River	Clinch River Study Steering Committee (1967)
1960	3.2	Dam closed; surface level raised 7.6 cm (3 in.)	Kolehmainen and Nelson (1969)
May 1963	6.0	Completion of Melton Hill Dam	Kolehmainen and Nelson (1969)
1967	8.1[d]	None reported	McMaster (1967)
1969	10.5	None reported	Kolehmainen and Nelson (1969)
November 1979	4.6	Lake level gradually dropped from 227.1 to 226.2 m (745 to 742 ft) MSL due to potential leakage and instability of the dam. Construction of a berm to stabilize the dam was completed in March 1980.	Oakes, Shank, and Kelly et al. (in press)

[a]At normal pool elevation of 228.0 m (748 ft) mean sea level (MSL); at full pool (228.6 m or 750 ft MSL), the surface area is 17.9 ha (Krumholz 1954a).

[b]Kolehmainen and Nelson (1969).

[c]According to Lackey (1957, p. 15), ". . . in the summer of 1956 the main body of the lake had been drained, leaving a small pool of about one acre [0.4 ha] above the White Oak Dam."

[d]Same surface area was reported by Dahlman, Kitchings, and Elwood (1977) and Edgar (1978).

13.5 cfs (U.S. Geological Survey 1963 as cited in Clinch River Study Steering Committee 1967). Based on the average discharge and drainage area, White Oak Creek is one of the larger tributaries of the lower Clinch River but is considerably smaller than Poplar Creek, which is located about 14 km downstream of the mouth of White Oak Creek (Table 2.3).

In addition to the changes that resulted whenever the lake was drained (or partially drained), the accumulation of sediment over the years has altered the environment of White Oak Lake. Except in the creek channel near the east shore where the substrate is mostly small rubble and gravel, the lake bottom consists primarily of silt, clay, and organic matter. The average annual rate of sediment accumulation prior to 1953 was estimated to be 2832 m^3 (100,000 ft^3), or about 2 cm/year.*

Because the lake is small and shallow, the water retention time is very short. Based on the average annual inflow, the retention time has been estimated to be approximately 2 d when the gate in White Oak Dam is set at 227.1 m (745 ft), but less than 24 h when the gate elevation is 226.2 m (742 ft) (D. D. Huff, ORNL, unpublished data). During major storm events when retention time is minimal, large quantities of sediment can be transported through the watershed to the Clinch River (Edgar 1978). Even relatively small storms such as those during the late spring and summer of 1979 resulted in dramatic reductions in Secchi disc transparency (Fig. 2.3). During the early fall, however, rainfall was low, and light could reach the bottom of the lake for sustained periods of time. This occurrence probably explains the unexpected similarity between the mean transparency of White Oak Lake and the Clinch River (Table 2.4). Sedimentation and the short retention time may account for the limited abundance of macrophytes (*Elodea, Potamogeton,* and *Sagittaria*) in the lake.

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*Based on a lake surface elevation of 228.0 m (748 ft) and a surface area of 14.5 ha (35.87 acres) (Krumholz 1954a), and a lake volume of 171,324 m^3 (6,049,587) in June 1953 (Morton 1963, Table 10).

Table 2.3. Location, drainage area, and average annual discharge of tributaries to the Clinch River in a 21-km reach below Melton Hill Dam [Clinch River kilometer (CRK) 37.2]

N/A = Information not available. Source: Project Management Corporation (1975), Sect. 2.5.1.1, unless noted otherwise

Tributary	Confluence location (CRK)[a]	Drainage area (km^2)	Average annual discharge (m^3/s)[b]
White Oak Creek	33.5	15.5[c]	0.38 (13.5)[c,d]
Raccoon Creek	31.4	1.2[e]	N/A
Ish Creek	30.7	0.9[f]	0.05 (2)[f]
Caney Creek	27.4	21.4	0.40 (14)
Poplar Springs Creek	26.1	7.8	0.41 (5)
Grassy Creek	23.3	5.0	0.08 (3)
Poplar Creek	19.3	352.2	6.45 (228)[g]

[a]CRK 0.0 is at the confluence with the Tennessee River.

[b]Discharge in cfs in parentheses.

[c]At White Oak Dam (Edgar 1978).

[d]Estimated for the period 1953-55 and 1960-63 (five water years).

[e]Source: Oak Ridge Operations Land-Use Committee (1975).

[f]At 0.56 km above the mouth. Source: McMaster (1967).

[g]Period of record: 1960-1977. Value represents the sum of the average annual discharge of West Fork Poplar Creek (4.98 m^3/s or 176 cfs) and East Fork Poplar Creek (1.47 m^3/s or 52 cfs). Source: U.S. Geological Survey (1978).

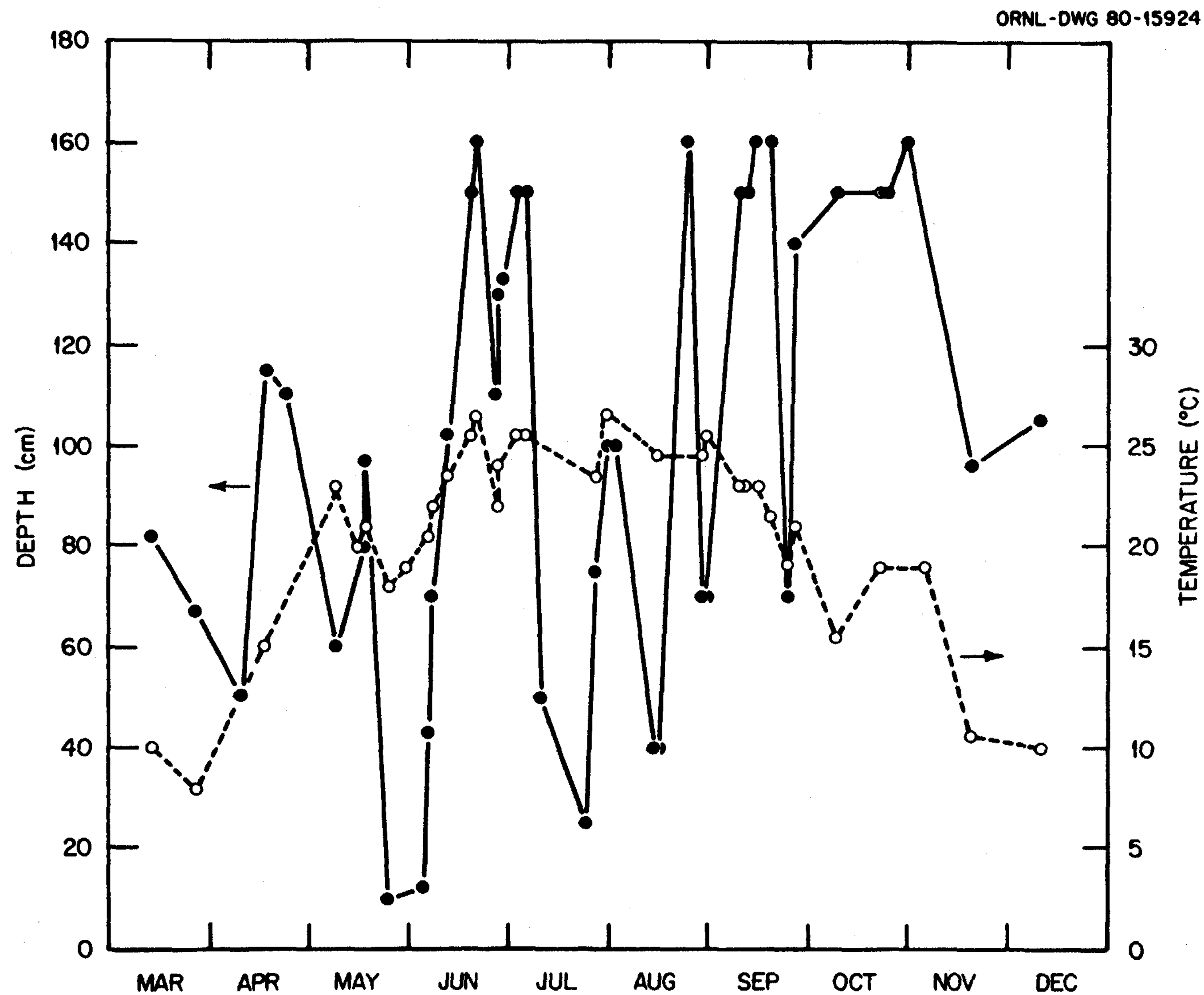

Fig. 2.3. Seasonal fluctuations in Secchi disc transparency and surface water temperature in White Oak Lake, March-December 1979 [station White Oak Creek kilometer (WOCK) 1.1]. Only temperature data collected between 0845 and 1100 h are shown. (•) = Secchi disc on bottom of lake.

Table 2.4. Comparison of various physical characteristics of the Clinch River, White Oak Creek embayment, and White Oak Lake in the vicinity of the biological sampling sites

The water temperature and transparency data were recorded concurrently with the collection of biological samples during the period March 1979–February 1980. N = number of measurements taken

	CRK 35[a]	CRK 31	WOCK 0.2[b]	WOCK 1.1
Temperature (°C)[c]				
Range	5.0–20.5	4.5–22.0	3.0–26.0	4.5–28.0
N	64	64	66	53
Secchi disk transparency (cm)				
Mean	103	94	70	102
Range	52–200	40–160	10–140	10–160
N	55	55	64	46
Maximum depth (m)	5.5	6.7	2.7	1.8 (0.9)[d]
Mean width (m)	107	115	17	8.1 (3.7)[d]

[a]Clinch River kilometer 35.

[b]White Oak Creek kilometer 0.2.

[c]At the surface.

[d]At an elevation of 227.1 m (745 ft) mean sea level (MSL); values in parentheses represent present conditions at lake level of 226.2 m (742 ft) MSL.

Water temperatures in the lake show a rather typical seasonal pattern (Fig. 2.3). Gradual warming occurs in early spring, and maximum temperatures occur during the summer (June through August). Although temperature data recorded during periods of biological sampling (usually between 0900 and 1300 h) indicated a maximum temperature of 28°C (Table 2.4), higher temperatures probably occurred. Maximum surface temperatures reported during a 1950-1953 limnological survey of the lake were 31°C at a location near the present sampling site (Krumholz 1954b, Table 26). Temperatures of 35°C and daytime pH values of 10 to 11 (probably as a result of photosynthesis) have been recorded in the very shallow northeastern end of the lake (Auerbach et al. 1974, p. 39).

At its present elevation of 226.2 m (742 ft) MSL, the lake has a surface area of about 4.6 ha (Oakes, Shank, and Kelly et al., in press), with open water extending about 400 m above the dam. Flooded standing timber that was not cleared when the lake was impounded (Krumholz 1954a) occurs in the shallow (<1 m) middle and upper regions of the lake. Duckweed is abundant in the lake and massive blooms of benthic and neustonic algae covered the northeastern end of the lake during much of the summer and fall (Auerbach et al. 1974, p. 39). Their periodic blooms in the lower region of the lake often made it impossible to tow nets for collecting zooplankton and ichthyoplankton (Sect. 3.1).

Currently, the mid and upper region of White Oak Lake is an extensive mudflat, although grasses and sedges have recently become established in most areas. This type of riparian growth differs from that which existed prior to the drawdown of the lake in 1979 when woody shrubs (e.g., black willow, ash, and buttonbush) were the dominant riparian species (Krumholz 1954a). Emergent vegetation (primarily rushes and cattail) still exists in the upper reaches of the lake.

2.3 WHITE OAK CREEK EMBAYMENT

When the level of Watts Bar Reservoir is raised to the summer pool elevation of 225.6 to 225.9 m (740 to 741 ft) MSL, backwater from the Clinch River extends upstream to White Oak Dam (WOCK 1.0), and an embayment is created. Such a condition exists from approximately mid-April through October, at which time the reservoir level is gradually lowered (Project Management Corporation 1975, Fig. 2.5-9). During most of the winter period (November through March), the area from the dam downstream about 600 m resembles a large mudflat. Depending on water level fluctuations in the Clinch River and, to a lesser extent, on those in White Oak Lake, this area is a site of active erosion-sedimentation processes (Edgar 1978). The substrates in the vicinity of station WOCK 0.2 consist of (1) gravel and sand and (2) silt and clay.

Water level fluctuations in White Oak Creek embayment are influenced not only by operation of Watts Bar Dam but also by operation of Melton Hill Dam, located 3.7 km upstream of the confluence with White Oak Creek. The Melton Hill Dam is a daily peaking facility with a generating capacity of 72 MW(e). Because of limited storage in the impoundment, releases at the dam are influenced, to a large extent, by the operation of Norris Dam (CRK 128.3), which impounds a large reservoir used for flood control, power generation, and recreation. The average monthly releases from these two dams follow a similar pattern (Waldrop and Johnson 1976, Table 1). Power demands and water releases at Melton Hill Dam fluctuate on a daily basis; thus water levels in lower White Oak Creek exhibit daily fluctuations. Locking operations at the dam may also have some effect on water levels in the study area.

Because of the proximity of White Oak Creek to Melton Hill Dam (3.7 km), the lower section of the creek is subjected not only to daily fluctuations in water level (usually <0.5 m) but also to dramatic changes in the velocity and direction of the current. On numerous occasions between late April and mid-August, strong (~30 cm/s) upstream flows were encountered at the sampling site (WOCK 0.2). This flow usually subsided within 15 min and was followed by a strong downstream flow of similar duration. Although upstream flows were also observed in Poplar Creek during a similar biological survey conducted in 1977-78 (Loar, in press), the velocities were considerably lower because of the greater distance between Poplar Creek and Melton Hill Dam (18 km).

Other studies have also demonstrated the existence of altered flow regimes in both White Oak Creek and other tributaries of the Clinch

River below Melton Hill Dam (Clinch River Study Steering Committee 1967; Project Management Corporation 1975). Pronounced upstream flows in White Oak Creek were observed when releases from the dam caused a rapid rise in the level of the river. When dye was added to the discharge at White Oak Dam, it ponded in the embayment below the dam when releases occurred at Melton Hill Dam. When these releases were terminated, the dye was released to the creek (Clinch River Study Steering Committee 1967). During preoperational studies conducted in 1974-1975 for the Clinch River Breeder Reactor Project, net flows into Caney Creek (Table 2.1) were observed on five of six sampling dates between March and November 1974. Upstream flows in Poplar Springs Creek occurred less frequently, and upstream velocities at both sites generally ranged from 3 to 9 cm/s (Project Management Corporation 1975, Sect. 2.7.2.3.4).

The frequent exchange between the water masses of lower White Oak Creek and the Clinch River influenced both the temperature and Secchi disc transparency of the embayment near the sampling site (WOCK 0.2). From May through July, the surface water temperature was generally 3 to 5°C higher than the river (Fig. 2.4) but was consistently lower than that of the lake. For a distance of about 400 m upstream of the mouth, a canopy formed by the mixed hardwood riparian vegetation covers much of the creek. Beyond this point, the embayment widens considerably and is the area previously referred to as a large mudflat in winter. Both the partial canopy and the periodic upstream movement of cooler water from the river have a moderating effect on the thermal regime at station WOCK 0.2.

Another unique characteristic of White Oak Creek embayment is the pronounced fluctuation in Secchi disc transparency (Fig. 2.5). Except during the winter, the transparency rarely exceeded 90 cm (annual mean = 70 cm, Table 2.4). The highly turbid nature of the embayment is most likely caused by the frequent alterations in flow, which may disturb the fine particulate bottom sediments in the upper regions of the embayment. During these sudden shifts in current velocity and direction, transparency was reduced by 15 to 20 cm for brief periods of time.

ORNL-DWG 80-15926

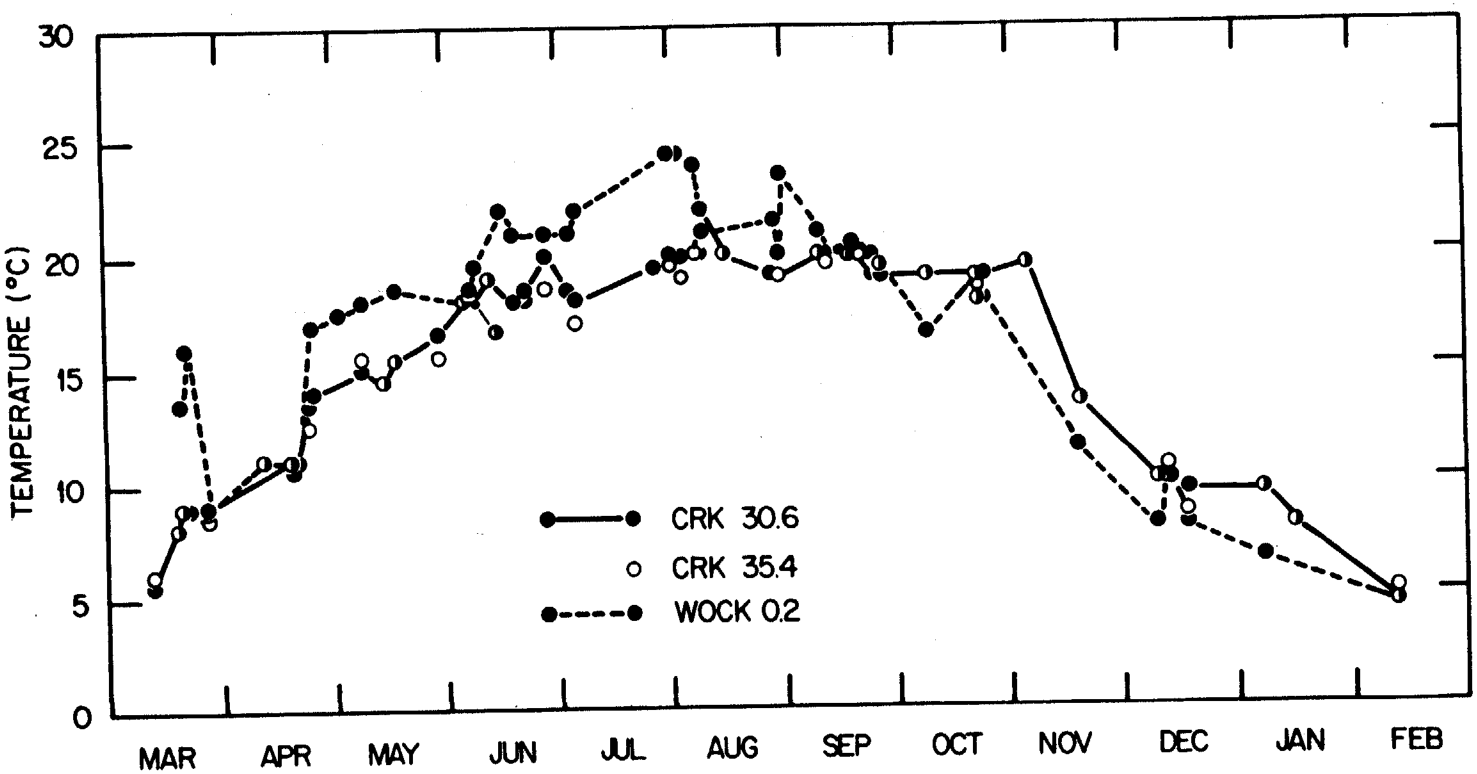

Fig. 2.4. Annual fluctuations in surface water temperatures at sampling sites in White Oak Creek, near the mouth, and in the Clinch River, March 1979-February 1980. The confluence of White Oak Creek and the Clinch River is located at Clinch River kilometer (CRK) 33.5. Only temperature data collected between 0845 and 1100 h are shown. WOCK = White Oak Creek kilometer.

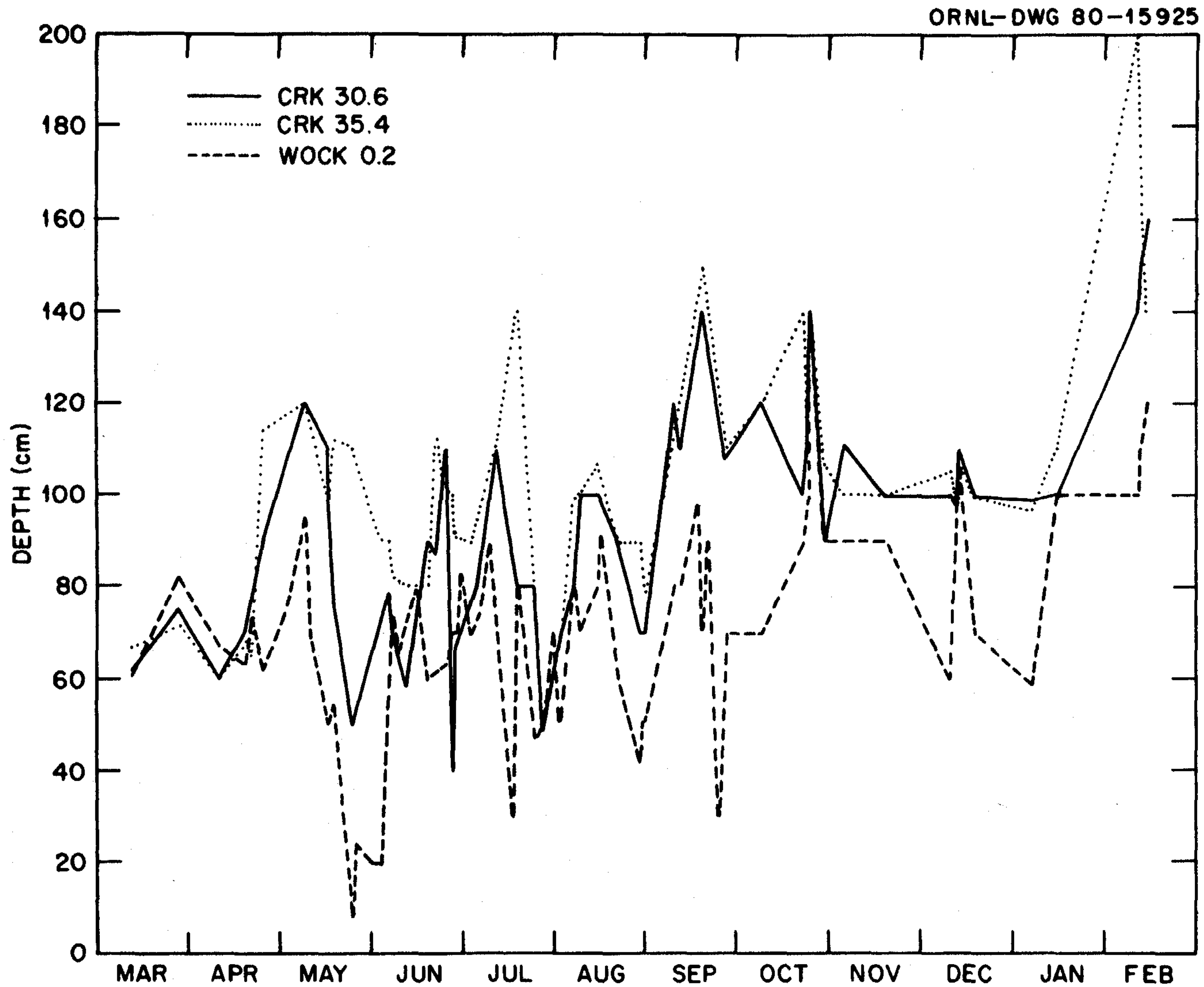

Fig. 2.5. Annual fluctuations in Secchi disc transparency at sampling sites in White Oak Creek near the mouth and in the Clinch River, March 1979–February 1980. The confluence of White Oak Creek and the Clinch River is located at Clinch River kilometer (CRK) 33.5. WOCK = White Oak Creek kilometer.

2.4 CLINCH RIVER

The Clinch River forms the southern and western boundary of the Oak Ridge–DOE Reservation for a distance of about 63 km, extending from CRK 78.8 on Melton Hill Reservoir to CRK 16.1, about 3.2 km downstream from the mouth of Poplar Creek. The headwaters are located in southwestern Virginia, and the river has a drainage area of 11,430 km^2 at its mouth near the Tennessee River kilometer (TRK) 913.4 (McMaster 1967). The study area was located in the tailwaters of the Clinch River below Melton Hill Dam (CRK 37.2). Sites were selected both upstream (CRK 35.4) and downstream (CRK 30.6) of the confluence with White Oak Creek (CRK 33.5).

Since May 1963, when the gates at Melton Hill Dam were closed (Fitz 1968), flows in the lower Clinch River have been regulated by releases at the dam. The average annual flow in this region of the river for the period 1964-1979 has been 153 m^3/s (5385 cfs) and has ranged from 85 m^3/s (2944 cfs) in 1966 to 229 m^3/s (8071 cfs) in 1974 (see references in Table 2.5). The maximum daily discharge recorded during this period was 990 m^3/s (34,996 cfs), which occurred on January 11, 1974. Maximum monthly flows typically coincide with the period of highest precipitation (January through March), and such a pattern was exhibited during the ORNL biological sampling program in 1979 (Table 2.5). With the exception of May and December, the mean monthly discharge in 1979 was higher than the historical average.

Since the dam is operated as a peaking hydroelectric facility and demand varies on a daily as well as seasonal basis, flows can be highly variable over a 24-h period, especially during the summer. Periods of no flow frequently occur from 12:00 P.M. to 6:00 A.M., when the demand is lowest (Project Management Corporation 1975, Table 2.7-44). Periods of no flow can also occur for longer periods of time (24 h), usually weekends, when the demand is reduced. In 1978, for example, there were 12 d when no water was released at Melton Hill Dam over a 24-h period, and 9 of these days occurred on weekends. No days of zero release occurred in 1979 (Tennessee Valley Authority, River Management Branch, provisional discharge data).

Table 2.5. Comparison of mean monthly discharge (m^3/s) in 1979 with historical discharges (1964-1979) at Melton Hill Dam

Discharge in cfs in parentheses

	1979[a]		1964-1979[c]
	Mean	Range[b]	
January	334 (11,806)	53-582 (1,875-20,558)	237 (8,379)
February	294 (10,377)	105-486 (3,695-17,154)	185 (6,540)
March	378 (13,340)	61-704 (2,154-24,846)	153 (5,397)
April	166 (5,863)	54-337 (1,920-11,904)	131 (4,624)
May	103 (3,647)	49-266 (1,721-9,404)	110 (3,878)
June	176 (6,209)	79-275 (2,788-9,708)	133 (4,701)
July	207 (7,303)	116-306 (4,079-10,804)	138 (4,859)
August	231 (8,168)	151-316 (5,333-11,163)	165 (5,838)
September	184 (6,503)	96-247 (3,396-8,729)	136 (4,813)
October	195 (6,895)	74-356 (2,600-12,563)	112 (3,962)
November	185 (6,539)	27-294 (946-10,383)	133 (4,711)
December	152 (5,377)	17-293 (588-10,350)	199 (7,016)
Annual average	217 (7,662)		153 (5,385)

[a]Values based on provisional mean daily discharge data provided by the Tennessee Valley Authority (TVA), River Management Branch, Knoxville, Tennessee.

[b]There were no days of zero release in 1979.

[c]Values were calculated using both data reported by Project Management Corporation (1975), Table 2.5-3, for 1964-1973 and data received from TVA for 1974-1979.

Water level fluctuations in the Clinch River study area are controlled by operation of both Melton Hill Dam and Watts Bar Dam, which is located on the Tennessee River (TRK 852.6) about 61 km below the confluence of the Clinch and Tennessee rivers (TRK 913.4). Daily fluctuations in this region of the river occur primarily from releases at Melton Hill Dam, while seasonal fluctuations are the result of Watts Bar Reservoir operation. The study area is located in upper Watts Bar Reservoir, and prior to construction of the dam at CRK 37.2, the reservoir extended upstream to CRK 45.1 (Dahlman, Kitchings, and Elwood 1977). The mean annual fluctuation of the reservoir is 1.8 m, with seasonal fluctuations of 0.6 m and 0.3 m during the winter and summer respectively. Changes in pool elevation occur in April and October. The Tennessee Valley Authority has followed this plan of normal operation closely since operation of the Watts Bar Dam commenced in 1942 (Project Management Corporation 1975, Sect. 2.5.1.4).

The release of cold hypolimnetic water at Norris Dam (CRK 128.3) can influence water temperatures throughout Melton Hill Reservoir because of its short water retention time (about 8.5 d) (Tennessee Valley Authority 1976). Consequently, the water released through the turbines at Melton Hill Dam (CRK 37.2), which is withdrawn from the lower level of the reservoir [intake depth and maximum reservoir depth are 16 and 23 m respectively (Jenkins 1967; Urban, Higgins, and Brooks 1979)], is relatively cold during the summer. Surface temperatures in the Clinch River just below Melton Hill Dam, for example, rarely exceed 21°C (Fig. 2.4; U.S. Geological Survey 1978). From June through October, water temperatures at both the upstream and downstream sampling sites remained relatively constant (between 18 and 20°C). Differences in temperature between the two sites were generally insignificant (<1°C). Although White Oak Creek (CRK 33.5) had little influence on the temperatures at station CRK 30.6, it did affect the Secchi disc transparency at this site. Mean transparency was lower at CRK 30.6 than at the upstream site. Moreover, the sharp fluctuations in transparency that occurred at the downstream site between May and July were not observed at CRK 35.4 (Fig. 2.5).

Since maximum current velocities below Melton Hill Dam may exceed 90 cm/s (Project Management Corporation 1975, Tables 65 through 70), scouring occurs in the channel of the river, and the substrate consists of exposed bedrock. Downstream from CRK 22.5 (near Gallaher Bridge on Route 58), appreciable deposition of sediments on the bed of the river begins, but upstream of this point (and in the study area), deposition is confined to regions immediately adjacent to the banks (Carrigan and Pickering 1967, as cited in Clinch River Study Steering Committee 1967). In these areas, the composition of the substrate consists mostly of fine particulates (clay, silt, and fine sand), although coarser substrates (gravel and small rubble) were also encountered at the two study sites. The high current velocities and the fluctuation in current velocity and water level may also account for the absence of macrophytes at the two sites. Sparse macrophyte growth, however, was observed in other studies conducted downstream from station CRK 30.6 (Loar, in press, Sect. 1.2.2).

From spring through early fall, when water levels are highest, much of the riparian vegetation is partially submerged, thus providing potential cover for many aquatic species. Along the north shoreline of the river (where sampling of the fish populations was conducted), vegetation at the upstream site consisted of large willows and various shrub species which were partially submerged by the elevated water levels. The zone of riparian vegetation is narrow, with frequent open areas adjacent to the bank. More extensive cover along the shoreline occurs downstream of the Route 95 bridge (CRK 35.0). Overhanging and submerged tree limbs, shrubs, and tree stumps are characteristic of this area. Dominant riparian vegetation consists of shrubs and various hardwood species (primarily sycamore and red maple).

3. METHODS

3.1 BIOLOGICAL SURVEY

Biological sampling of the aquatic environment in the vicinity of Oak Ridge National Laboratory (ORNL) was conducted between March 12, 1979, and June 2, 1980. The phytoplankton, zooplankton, benthic macroinvertebrate, and fish communities were sampled over a 12-month period from March 1979 through February 1980. Because of the seasonality associated with fish spawning activities, ichthyoplankton (fish eggs and larvae) were sampled between March and September 1979. Periphyton sampling was initiated in early June 1979 and terminated 12 months later. A summary of the sampling program is presented in Table 3.1.

Several factors were considered in the initial design of this program, in addition to the usual constraints of money and manpower that are placed on studies of this nature. The sampling methods (gear types) and laboratory procedures chosen were those that had previously been shown to provide reliable information on both qualitative (species composition) and quantitative (species abundance) parameters (e.g., Edmonson and Winberg 1971; U.S. Environmental Agency 1978; Vollenweider 1969; Welch 1948). The selection of sampling frequencies is an important factor in the characterization of temporal fluctuations in population abundance and should be based, at least in part, on the population dynamics of the species making up the community. Thus, for example, phytoplankton, which exhibit rapid turnover rates during the warmer months, were sampled at two-week intervals from March through October and at four-week intervals from November to February. The results from a similar study conducted in the vicinity of the Oak Ridge Gaseous Diffusion Plant (ORGDP) were also evaluated to ensure that the sampling program (e.g., sampling frequencies and field and laboratory techniques), as initially designed, was appropriate for meeting the objectives of the study (Sect. 1). Information obtained during the ORGDP ichthyoplankton survey was particularly useful in this regard.

Field sampling was conducted by staff in the Environmental Sciences Division (ESD) at ORNL. Laboratory analyses (primarily identification

Table 3.1. Summary of the ORNL aquatic biological sampling program, March 1979–June 1980

Locations of the eight sampling sites are shown in Fig. 2.1

Community	Stations[a]	Method(s)	Approximate frequency	Total no. sampling dates[b]	No. samples collected/ station/date	Total no. samples (all stations)[c]
Phytoplankton	1-4	2-L Kemmerer	Biweekly (March-October) Monthly (November-February)	21 (1-3) 20 (4)	2	166
Zooplankton	1-4	Clarke-Bumpus	Same as above	21 (1-3) 15 (4)	2	156
Ichthyoplankton	1-5	0.5-m diameter plankton nets	Weekly (March-July) Biweekly (August-September)	25 (1,2) 18 (3) 17 (4) 23 (5)	2	216
Periphyton	1-8	Floating vertical racks with six plexiglass slides	Monthly (June-October 1979 and March-May 1980) Bimonthly (November-February)	8 (1-3) 10 (4-6,8) 7 (7)	6[d]	426
Benthic macro-invertebrates	1-8	Ponar dredge (1-4) Surber sampler (5-8)	Monthly (March-October) Bimonthly (November-February)	8 (1-3) 6 (4) 9 (5-8)	3/5[e]	258
Fish	1-8	Stationary experimental gill nets (1-4)	Monthly (March-October) Bimonthly (November-February)	9 (1-3) 4 (4)	1	31
		Electroshocking (1-8)	Stations 1-4: Monthly (June-October; December)	6 (1-3) 4 (4)	1	30
			Stations 5-8: November and January	2 (5-8)		

[a] 1 = Clinch River Kilometer (CRK) 30.6; 2 = CRK 35.4; 3 = White Oak Creek Kilometer (WOCK) 0.2; 4 = WOCK 1.1 (White Oak Lake); 5 = WOCK 2.1; 6 = WOCK 2.7; 7 = WOCK 6.3; 8 = Melton Branch Kilometer (MBK) 0.6.

[b] Stations in parentheses (see footnote *a*).

[c] Values reflect the actual number of samples collected and analyzed. Where samples were scheduled but not taken (see text), appropriate notations have been made on the figures in Sect. 4.

[d] From June 1979 to March 1980, two slides (samples) each were used for identification and enumeration, biomass, and chlorophyll a determinations. Beginning in April 1980, identification/enumeration was discontinued and three slides were used for each of the other two analyses.

[e] Five samples at stations 1-4; three samples at stations 5-8.

and enumeration of genus and species) were performed by Tennessee Valley Authority (TVA) personnel at Norris, Tennessee (ichthyoplankton and benthic macroinvertebrates), and Muscle Shoals, Alabama (phytoplankton, zooplankton, and periphyton). All these analyses were performed at the TVA laboratories, with the exception of the benthic macroinvertebrate samples from White Oak Creek below ORNL, White Oak Lake, and Melton Branch. Because these samples contained low levels of radioactivity, they were analyzed at ORNL by TVA personnel from the Norris laboratory. Fish samples collected by gillnetting and electroshocking were processed by ESD staff members.

The information collected during this survey represents a significant contribution to the historical record on the aquatic ecology of the White Oak Creek watershed and the lower Clinch River. Depending on the needs of future investigators, raw data may be more useful than the summarized data presented in this report. Consequently, data on the abundance of each taxon (by replicate, date, and station) and the supplemental information recorded at the time the samples were taken (e.g., Secchi disc, water temperature, etc.) will be permanently stored on magnetic tape in the ORNL tape library (Tape No. X16587). The collection and analysis procedures used in this study are described below.

3.1.1 Phytoplankton

Replicate phytoplankton samples were taken just below the surface with a 2-L Kemmerer water sampler. Samples were taken near midstream at all sites except White Oak Lake, where the sampling site was located near the east shore about 100 m above the dam. After the lake level was dropped in late November, however, the site could not be reached (no boats could be launched because of the deep layer of silt and clay that was exposed around the entire lake), and phytoplankton had to be sampled at the dam. Samples were preserved in Lugol's solution in the field immediately after collection (Vollenweider 1969) and were refrigerated prior to their shipment to Muscle Shoals.

In the laboratory, a 15-ml subsample was taken from the sample bottle, placed in a modified Uthermöhl sedimentation cylinder, and allowed to settle for a minimum of 12 h. The phytoplankton in replicate 2.5-cm transects across the counting chamber were identified and enumerated at about 320X using an inverted microscope. One occurrence of an alga was treated as one counting unit (e.g., one crytomonad cell, one *Scenedesmus* coenobium, one *Melosira* filament, etc.). Identification of genus was made using several taxonomic references (Hustedt 1930; Smith 1933; Forest 1954; Desikachary 1959; Prescott 1962, 1964; Patrick and Reimer 1966; Cocke 1967; Whitford and Schumacher 1969; Tiffany and Britton 1971; Drouet 1973; Drouet and Daily 1973).

3.1.2 Zooplankton

Replicate zooplankton samples were taken with a Clarke-Bumpus sampler equipped with a No. 20 mesh (76 μm) net. Horizontal tows were taken just below the surface near midstream in the Clinch River and White Oak Creek embayment and near the east shore in lower White Oak Lake. Towing times at the Clinch River sites were 3 min between March and October (average volume of water filtered was 1.17 m^3) and 5 min from November to February. Most samples were collected in the morning between 0800 and 1200 h. In the White Oak Creek embayment, 3-min tows were taken initially but had to be reduced to 2 min, beginning in June after a tree had fallen and blocked the stream. Tows were also 2 min long in White Oak Lake because of the limited area that had sufficient depth for towing. Between July and November, samples could only be taken on 50% of the dates scheduled because the high abundance of filamentous algae in the lake caused the net to clog rapidly. No zooplankton samples were taken after the lake level was lowered in late November. The average volume of water filtered in a 2-min tow was 0.50 and 0.92 m^3 at the embayment and lake sites respectively.

Zooplankton sampling was conducted concurrently with the collection of phytoplankton samples. On each sampling trip, the time of collection, weather condition, Secchi disc transparency, and water temperature were recorded. Immediately after collecting the sample, the zooplankton were narcotized in commercial-grade Neosynephrine and preserved in 5% formalin.

In the laboratory, the sample was diluted or concentrated, as appropriate, to obtain a count of about 100 organisms in a 1-ml Sedgwick-Rafter cell. For each sample, four 1-ml subsamples were examined, and all organisms were identified to species, or the lowest possible taxon, and counted. A scan of the remaining sample was also made to identify the rarer species. Taxonomic references used in the zooplankton analysis included Harring and Myers (1926); Ahlstrom (1940, 1943); Voight (1956); Edmondson (1959); Goulden (1968); Deevey and Deevey (1971); Ruttner-Kolisko (1974); and Brooks (1975).

3.1.3 Ichthyoplankton

Replicate ichthyoplankton samples were collected near midstream in the Clinch River by towing a 2-m-long, 0.5-m-diameter plankton net against the current. The net, which had a 0.75-m diameter expanded collar and was composed of 243 µm-mesh Nitex, was towed about 18 m behind a boat. The same gear was used in White Oak Lake where towing was conducted near the east shore from the dam approximately 300 m upstream. Since the creek above the lake is shallow, a 1.3-m-long, 0.5-m-diameter conical net (153 µm-mesh Nitex) without the expanded collar had to be used at this station (WOCK 2.1). Stationary net samples were taken by suspending the net in the water for 15 min and allowing the current to carry drifting organisms into the net. At all four of the above sites, sample volumes and towing velocities were determined by means of an impeller-type flowmeter (General Oceanics No. 2030) suspended in the center of the mouth of the net.

In the Clinch River, nets were towed for 5 min at velocities of approximately 1.5 m/s, resulting in sample volumes of about 100 m^3. Prior to mid-May and in late September, 8-min tows were taken at an average velocity of 2.2 m/s, resulting in sample volumes of about 215 m^3. Because of the shallow nature of White Oak Lake, tows were reduced to 2 min and velocities ranged between 1 and 2 m/s. Samples volumes were about 50 and 66 m^3 at stations WOCK 1.1 (White Oak Lake) and 2.1 respectively.

The same gear used at the above sites could not be used to sample ichthyoplankton in White Oak Creek embayment. To sample this environment, which consisted of submerged tree limbs, stumps, and brush, a Sears Homelite trash pump with a maximum capacity of 1.46 m^3/s (385 gpm) was employed. Similar gear has been used by TVA to sample shallow, near shore areas of reservoirs (R. Wallus, personal communication). Water was filtered through the 243 μm-mesh net (see above) which was held at the side of the boat by a specially constructed metal brace. Replicate samples were taken just below the surface (0.25 m) and, on occasion, near the bottom for a period of 15 min, resulting in a sample volume of 16.7 m^3. The pump was not operated at the maximum rate because of (1) difficulties encountered in controlling the boat and (2) potentially greater damage to the larvae during pump passage.

Filtered samples were washed down into a screened collecting bucket at the cod end of the net and were preserved in the field in 5% formalin. Supplemental information recorded on each ichthyoplankton sampling trip included time of sample, weather conditions, Secchi disc transparency, and water temperature.

In the laboratory, samples were poured into black enamel pans, and ichthyoplankton were separated from detritus and zooplankton with the aid of an illuminated magnifying lens. All fish eggs and larvae in the sample were identified to the lowest possible taxon according to Hogue, Wallus, and Kay (1976), and larvae (to a maximum of 100 individuals per taxon) were measured to the nearest millimeter.

3.1.4 Periphyton

Surface-floating samplers, with styrofoam floats and a submerged rack containing six plexiglass slides, were used to collect periphyton. The upper end of the vertically suspended slides was about 30 cm below the surface of the water. During low-flow periods, the samplers at stations WOCK 6.3 and Melton Branch kilometer (MBK) 0.6 were suspended at a 45° angle instead of vertically. To anchor the sampler in place, a lead brick was attached at the end of a cord from the bottom of the sampler (cord length varied depending upon the depth at the sampling site). The exposure period in the field was 28±0.1 days, except at station WOCK 6.3. Periods of no discharge occurred periodically during the summer at this site; as a result, no samples were collected in June and August, and the July and September samples were only exposed for 14 and 18 d respectively. In early September, the periphyton sampling site was moved about 400 m upstream (WOCK 6.7). No samples were collected in April because of high flows in the creek. Vandalism and fluctuating and/or high water levels resulted in no samples at stations CRK 30.6, 35.4, and WOCK 0.2 on two occasions.

At the beginning and end of the colonization period, the time of day, weather conditions, water temperature, and Secchi disc transparency or depth (upper White Oak Creek and Melton Branch sites) were recorded. The slides to be used for each of the three analyses (cell counts, biomass, and chlorophyll) were selected at random, placed in prelabelled plastic bags, and quickly frozen on dry ice in the field. They were immediately shipped to Muscle Shoals, usually arriving at the TVA laboratory within 24 to 48 h of their collection from the field.

For direct cell counts (identification and enumeration), the algal growth was scraped from both sides of the slide with a neoprene policeman and rinsed with distilled water. After the sample was diluted, as necessary, and preservative added, a subsample was taken and allowed to settle for approximately 12 h in a sedimentation cylinder. The dilution volume (usually 200 to 1000 ml) and the volume of the subsample (1 to 5 ml) were dependent upon the amount of growth on the slide. Organisms were identified to genus and enumerated with an inverted microscope at about 320X. Taxonomic references used in the identification of periphyton were the same as those used in the phytoplankton analysis.

Biomass determinations were made by scraping the growth from both sides of the slide into a preweighed crucible. The residue was dried at 105°C for 12 h (or until a constant weight was obtained), weighed, then ashed in a muffler furnace at 600°C for 1 h and weighed again. The difference between the two weights is the ashfree dry weight or organic weight of the sample.

To determine the concentrations of chlorophyll a and phaeophytin a, both sides of the slides were scraped and rinsed with 90% acetone, resulting in extract volumes of 20 to 50 ml. After the extract was homogenized and steeped for a minimum of 12 h, it was clarified by centrifugation, and the supernatant decanted into a clean centrifuge tube. The absorbance (optical density) of the extract was read at 750 and 630 nm in a spectrophotometer. If dilution was necessary, 2 ml of the extract was added to 10 ml of 90% acetone. The amount of phaeophytin a, a natural degradation product of chlorophyll a, was determined by examining the optical density at 663 nm before and after acidification. To correct for the presence of phaeophytin a, chlorophyll a concentrations were computed using the equation of Weber (1973), as modified for the calculation of chlorophyll a concentrations in milligrams per square meter. All analyses were completed within 5 d of the collection of the slides from the field.

3.1.5 Benthic macroinvertebrates

Because of differences in the depth of White Oak Creek in the upper and lower portions of the watershed (and the Clinch River), two types of equipment were used to sample benthic macroinvertebrates. At the four stations located above White Oak Lake, a Surber sampler (0.09 m^2 or 1 ft^2) with a 253-μm mesh net was used. Triplicate samples were taken on a transect across the stream. The transects at the four sampling stations were all located below pools and just above a riffle area. As a result, the substrate and flow characteristics among the sites were similar. Qualitative samples were also taken from a variety of habitats in October. Samples were placed in small plastic jars and preserved in 10% formalin. Supplemental data on the time the sample was taken, weather conditions, water temperature, depth and general nature of the substrate for each sample, and width of the stream at the transect were recorded.

Benthic macroinvertebrates at the other four stations were collected with a hand-operated Ponar dredge that is 15 × 15 × 15 cm. Five samples were taken across the lake or river at each station. The presence of large boulders, bedrock, and occasional strong currents precluded sampling at equal intervals along the two transects in the Clinch River. Instead, the river was sampled near the two banks where some deposition had occurred. The time, weather conditions, water temperature, and Secchi disc transparency were recorded for each sampling trip. Samples collected from White Oak Lake and White Oak Creek embayment were sieved, placed in large glass jars, and preserved in 70% isopropanol in the field. At the Clinch River sites, the entire contents of the dredge were placed in a large plastic bag and returned to the laboratory where the contents were sieved through a No. 35 mesh (500-μm) brass screen. The sample was washed from the screen and preserved in 70% isopropanol.

In the laboratory, all samples were washed (or rewashed) using a standard No. 60 mesh (250-μm) sieve and placed in a large white tray. Organisms were separated from the debris with forceps under a table-mounted magnifier. Specimens were preserved in vials containing 70% ethanol. Identification and enumeration, generally to genus, were made using dissecting microscopes. Permanent slide mounts of chironomids were prepared in order to identify selected individuals to genus and species. Taxonomic references used in this study included Pennak (1953); Usinger (1954); Beck (1976); Edmunds, Jenson, and Berner (1976); and Wiggins (1977).

3.1.6 Fish

Because of gear selectivity, the most reliable estimates of species composition and relative abundance in reservoirs are obtained by using a combination of methods (Bennett and Brown 1969; Crandall, Lyons, and Luebke 1978). In the present study, electroshocking and gillnetting were employed in White Oak Lake, White Oak Creek embayment, and the Clinch River, and a backpack electroshocker was used to sample the populations in upper White Oak Creek and Melton Branch.

Stationary experimental (multifilament) nylon gill nets were set perpendicular to the shore (the east shore of White Oak Lake and the north shore of Clinch River), whenever possible, for a 24-h period. Nets used in the lake and at the two river sites were 48.5 × 1.8 m and consisted of six 7.6-m panels (1.9-, 2.5-, 3.2-, 3.8-, 5.1-, and 7.6-cm bar mesh). Because of the narrowness of White Oak Creek at station White Oak Creek kilometer (WOCK) 0.2, a smaller 3-panel net of 22.9 × 1.8 m and 1.9-, 3.2-, and 5.1-cm bar mesh was used and was set diagonally across the stream. Supplemental data recorded with each sample included time of day (when the net was set and when it was removed), weather conditions, water temperature, and Secchi disc transparency.

At the four sites on upper White Oak Creek (above the lake), fish were collected using a portable Dirigo Electrofisher 500 mounted on a backpack frame. Shocking was conducted along a 50-m reach of the creek upstream from the periphyton and benthic macroinvertebrate sampling sites. An additional 50 to 100 m of stream were sampled at stations MBK 0.6 and WOCK 2.7 and 2.1 (January only). At the other four sites, a Smith-Root Type IV electrofisher, which delivered a pulsed direct current through a single boom, was used. Electroshocking was conducted along a 150-m section of the shoreline in the vicinity of the gill net sets. At station WOCK 0.2, however, fish were collected from a 75-m section on each side of the embayment. Information was recorded on the time of day, weather conditions, water temperature, transparency (except at the four upper White Oak Creek sites), and the length of shoreline sampled.

Several problems were encountered during the course of the fish sampling program. Because of the abundance of filamentous algae in White Oak Lake during September and October, electroshocking was, for the most part, ineffective because of the difficulty in recovering stunned fish. Likewise, gill nets could not be set in the lake after July. Difficulties with the electroshocking equipment (presumably because of the high conductivity of the water) were encountered in late October at stations WOCK 1.1 and 0.2 and again in December at WOCK 0.2. Sampling on both occasions coincided with peaks in the concentration of total dissolved solids in (1) White Oak Lake and two tributaries to the lake and (2) White Oak Creek just above the lake (Oakes et al., in press). Finally, fluctuating water levels in the river and White Oak Creek embayment prevented deployment of the nets in the same position (perpendicular to the bank) at all sites on every sampling date. Because of these problems and the differences in the environments (habitats) at the various sites (Sect. 2), data on species abundance were not computed on a catch-per-unit-effort basis.

All fish collected by gillnetting and electrofishing were placed in large plastic bags and returned to the laboratory. The samples were frozen until they could be processed, at which time data were recorded on weight, sex, gonadal development, and total length. Identification to species was made using the taxonomic keys of Eddy (1969), Etnier (unpublished), and Pflieger (1975).

3.2 TRACE ELEMENT ANALYSIS OF FISH

Fish collected at five stations in 1979 were analyzed to determine the concentration of seven trace elements (Cd, Cr, Cu, Pb, Hg, Ni, and Zn) in axial muscle. A total of 20 fish representing three species was collected by gillnetting at stations Clinch River kilometer (CRK) 30.6 and 35.4 in March (Appendix D-1). In December, attempts were made to collect ten bluegill of approximately the same size from each of five sites: White Oak Lake, White Oak Creek embayment, the Clinch River near CRKs 30.6 and 35.4, and Melton Hill Reservoir (Appendix D-2). Because the level of White Oak Lake had been lowered (Sect. 2.1), the boat outfitted for electroshocking could not be used. Therefore, bluegill from the most recent routine electroshocking collection (August 30) were used instead (Appendix D-3). Largemouth bass collected from White Oak Lake in June and July were also analyzed. After collection, all fish were frozen until the analyses could be performed.

In the laboratory, fish were weighed and measured, and two 1- to 5-g samples of axial muscle were taken from the dorsal musculature just above the lateral line. One sample was analyzed for total mercury by using a perchloric acid-nitric acid digestion (Feldman 1974) and by analyzing the solution through flameless atomic absorption spectroscopy. The second sample was placed in a platinum crucible and ashed overnight at 480°C. The following day a series of 1 to 1 ultrex HNO_3 additions (initially 5 ml, then 3 ml, and finally 1 ml), separated by 1-h periods of heating to near boiling, were made. After the addition of 1 ml of 1 to 1 ultrex HNO_3, the solution was cooled, transferred to a 25-ml volumetric flask, and analyzed by graphite furnace atomic absorption. Standard addition techniques, the background corrector, and standard reference materials (National Bureau of Standards bovine liver) were used in all analyses.

3.3 STATISTICAL ANALYSES

Statistical analysis of the biological data was conducted on three levels.

1. Stations were compared with one another using an index of similarity. The purpose of this approach was to integrate genus- and species-level abundance data into fewer numbers, with considerable interpretive value.
2. In order to identify taxa responsible for the dissimilarities found in level one, patterns of abundance were investigated at a higher taxonomic level (e.g., phylum and order) by analysis of variance.
3. Finally, when two stations appeared very similar in terms of their dissimilarity coefficients and the univariate analysis of variance, a decision was made regarding the importance of detecting *any* significant differences among the stations. If such a comparison was judged to be important, a multivariate analysis of variance was performed using all higher-level taxonomic groupings.

Although two samples were analyzed for each station-date combination (three in the case of periphyton biomass and chlorophyll a for April through June 1980), these replicates were in the nature of subsamples and did not represent variation within the station. Consequently, the mean of the two replicates was used in all analyses, rather than treating the two samples as independent observations.

At the first level of analysis, Bray-Curtis dissimilarity coefficients (Boesch 1977) were calculated for each collection date for the phytoplankton, zooplankton, periphyton, and benthic macroinvertebrate communities. The coefficient is computed as

$$D_{jk\ell} = \frac{\sum_i |X_{ij\ell} - X_{ik\ell}|}{\sum_i \left(X_{ij\ell} + X_{ik\ell}\right)} ,$$

where

$D_{jk\ell}$ = dissimilarity coefficient for the comparison between stations j and k on date ℓ,

$X_{ij\ell}$ = number of individuals of species i at station j on date ℓ,

$X_{ik\ell}$ = number of individuals of species i at station k on date ℓ.

The Bray-Curtis coefficient can range from 0 to 1, with 0 denoting identical distributions of the same species and 1 indicating that no species are shared by the two stations. A one-way analysis of variance was used to determine whether these dissimilarity coefficients, across all sampling dates, differed among station combinations. Residuals were examined for heterogeneity of variance.

At the second level of analysis, taxonomic groups that were particularly abundant were treated separately. A two-way analysis of variance, with collection date as a blocking factor, was used to detect differences among stations. Since there was only one observation per cell, the interaction mean standard error (MSE) was used to test station effects, the result being a conservative test due to an inflated error term. A log transformation was applied to the data prior to analysis to reduce heterogeneity of variance. If significant differences among stations were indicated, a Duncan's multiple range test was used to sort the station means. An examination of the residuals revealed no extreme (greater than a threefold difference) heterogeneity of variance. The taxonomic groups that were analyzed in this manner included

- Phytoplankton
  - Chlorophyta
  - Chrysophyta (diatoms only)
  - Cyanophyta
  - Euglenophyta
- Zooplankton
  - Cladocera
  - Copepoda
  - Rotifera

Periphyton
  Chlorophyta
  Chrysophyta (diatoms only)

Benthic macroinvertebrates
  Chironomidae
  Pelecypoda
  Oligochaeta.

A multivariate analysis of variance was applied only to detect differences between the two Clinch River stations. The sampling date was used as a blocking factor. A log transformation was used, and, again, the residuals were examined for heterogeneity of variance. As in the univariate case, the interaction MSE was used to test for station effects. All statistical procedures, at this and the preceding two levels, were performed using the Statistical Analysis System (SAS Institute 1979).

4. RESULTS AND DISCUSSION

4.1 UPPER WHITE OAK CREEK

4.1.1 Periphyton

Taxonomic composition

Diatoms were the most abundant group composing the periphyton communities at each of the four sites in the upper White Oak Creek watershed (above White Oak Lake). Relative abundance of diatoms ranged from 91 to 94% at all stations except White Oak Creek kilometer (WOCK) 2.7, where diatoms and green algae (Chlorophyta) made up 75 and 24%, respectively, of the total periphyton abundance. The Chlorophyta were the second most abundant group at each of the other sites, but their relative abundance was low, ranging from 6.0% at station WOCK 2.7 to 8.7% at station WOCK 6.3.

Although the genus *Achnanthes* (Chrysophyta: Bacillariophyceae) was the most abundant taxon at all sites, relative abundance varied considerably. For example, this genus alone accounted for more than 91% of the total periphyton numbers (all groups combined over the entire sampling period) at WOCK 2.7. The relative abundance of *Achnanthes* was much lower at stations WOCK 2.1 (36%), 6.3 (37%), and Melton Branch kilometer (MBK) 0.6 (63%). Other diatoms found in relatively high numbers included *Navicula* (relative abundance ranged from 13 to 18% at these three sites), *Gomphonema* (17% at WOCK 6.3), and *Surirella* (20% at WOCK 2.1).

The most abundant green alga at all sites was *Stigeoclonium*, although *Ankistrodesmus* densities were also relatively high at MBK 0.6 and WOCK 2.1. The numerical dominance of *Oscillatoria* characterized the blue-green algae (Cyanophyta) at all sites. Although it was an insignificant component of the periphyton communities in the study area, the total numbers found at station WOCK 2.7 exceeded, by a factor of approximately 5, the total number found at stations WOCK 2.1 and MBK 0.6 (same number of samples were taken at each site). The other major groups were infrequently found and were represented by only one or two genera (Appendix A-1).

In addition to direct observations of abundance based on cell counts, data were collected on chlorophyll a content and biomass of the periphyton. The temporal and spatial distribution of each of these three measures of abundance is presented in the following sections.

Cell counts

At stations WOCK 2.1 and 2.7, diatom abundance generally increased during the summer and reached a peak in the fall (October) (Fig. 4.1). The decline in density during the fall at station MBK 0.6 could not be attributed to any single taxon but rather was reflective of an overall decline in periphyton abundance. Clearing the vegetation from a 25-m-wide strip along the gravel road that parallels Melton Branch near MBK 0.6 may have contributed to the sharp increase in density observed during the winter. The removal of this vegetation, which was first observed in early January, could have resulted in greater light availability, since the vegetation near the stream (mostly small shrubs) was completely removed to the soil surface. The temporal pattern observed at station WOCK 6.3, on the other hand, may simply reflect the difference in sampling methodology (i.e., shorter colonization periods and missing samples) between the site and those downstream where colonization periods were similar and no samples were missed (Sect. 3.1).

Peaks in the abundance of Chlorophyta generally coincided with periods of maximum diatom densities (Fig. 4.2). Typically, the abundance of green algae declines during the colder periods of the year when diatoms compose the majority of the periphyton community. Although such a pattern was found at stations WOCK 6.3 and 2.7, densities at WOCK 2.1 remained high throughout the winter because of shifts in the abundance of three genera. While densities of the filamentous green alga, *Stigeoclonium*, declined from 46,595 filaments/cm^2 in November to 9,101 filaments/cm^2 in January, densities of two genera, *Chlamydomonas* and *Gloeocystis*, not found in November had increased to 12,068 cells/cm^2 and 24,336 colonies/cm^2, respectively, by January.

The spatial distribution of periphyton densities, as measured by direct counts, in upper White Oak Creek watershed was examined by a

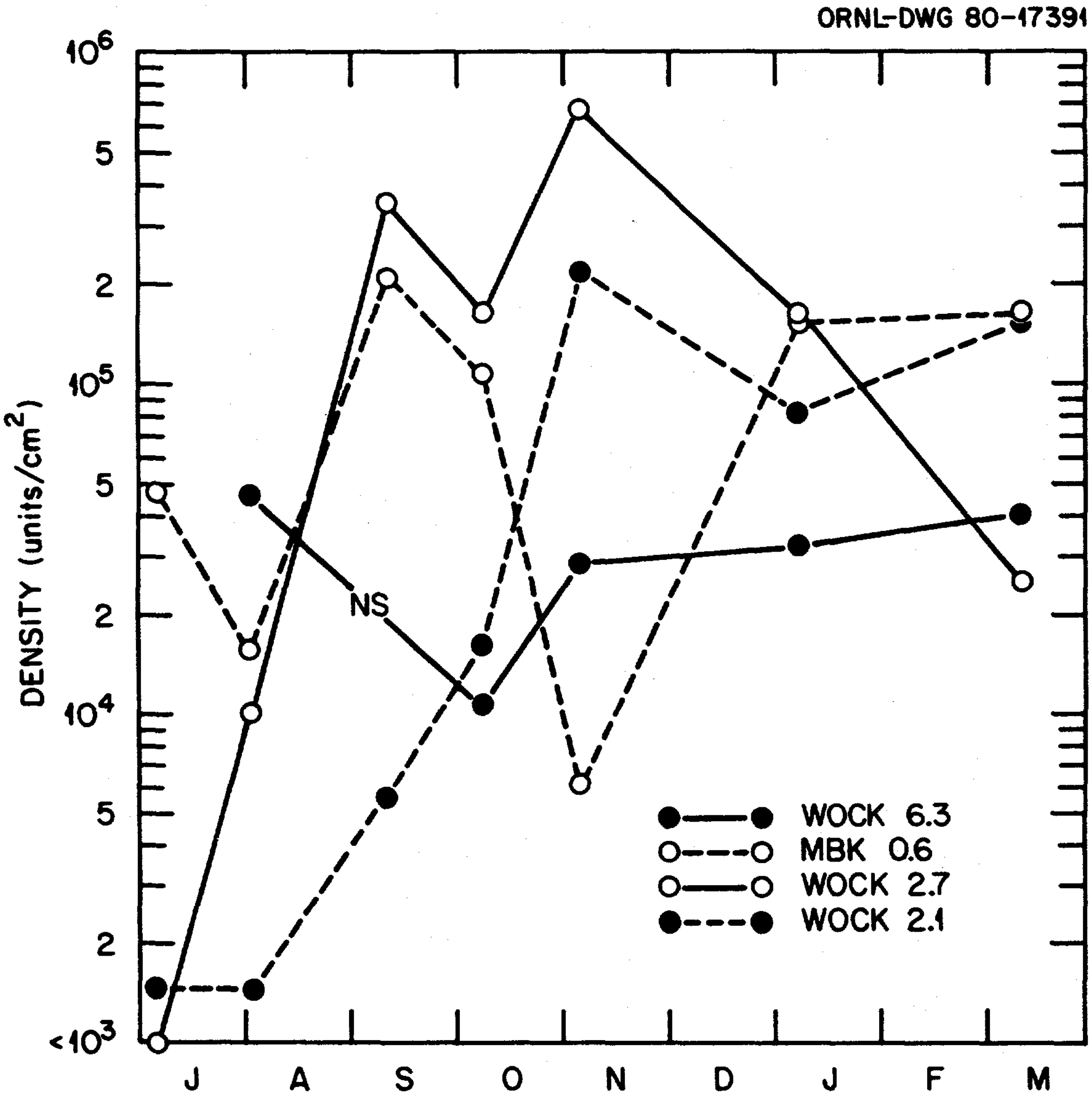

Fig. 4.1. Temporal fluctuations in the density of diatoms (units/cm^2) on plexiglass slides at four sites in upper White Oak Creek watershed, July 1979–March 1980. Dates shown on the graph represent the last day of the 28-d colonization period (14 and 18 d for the August and October samples, respectively, at WOCK 6.3). For colonial forms, 1 colony = 1 unit. NS = no samples.

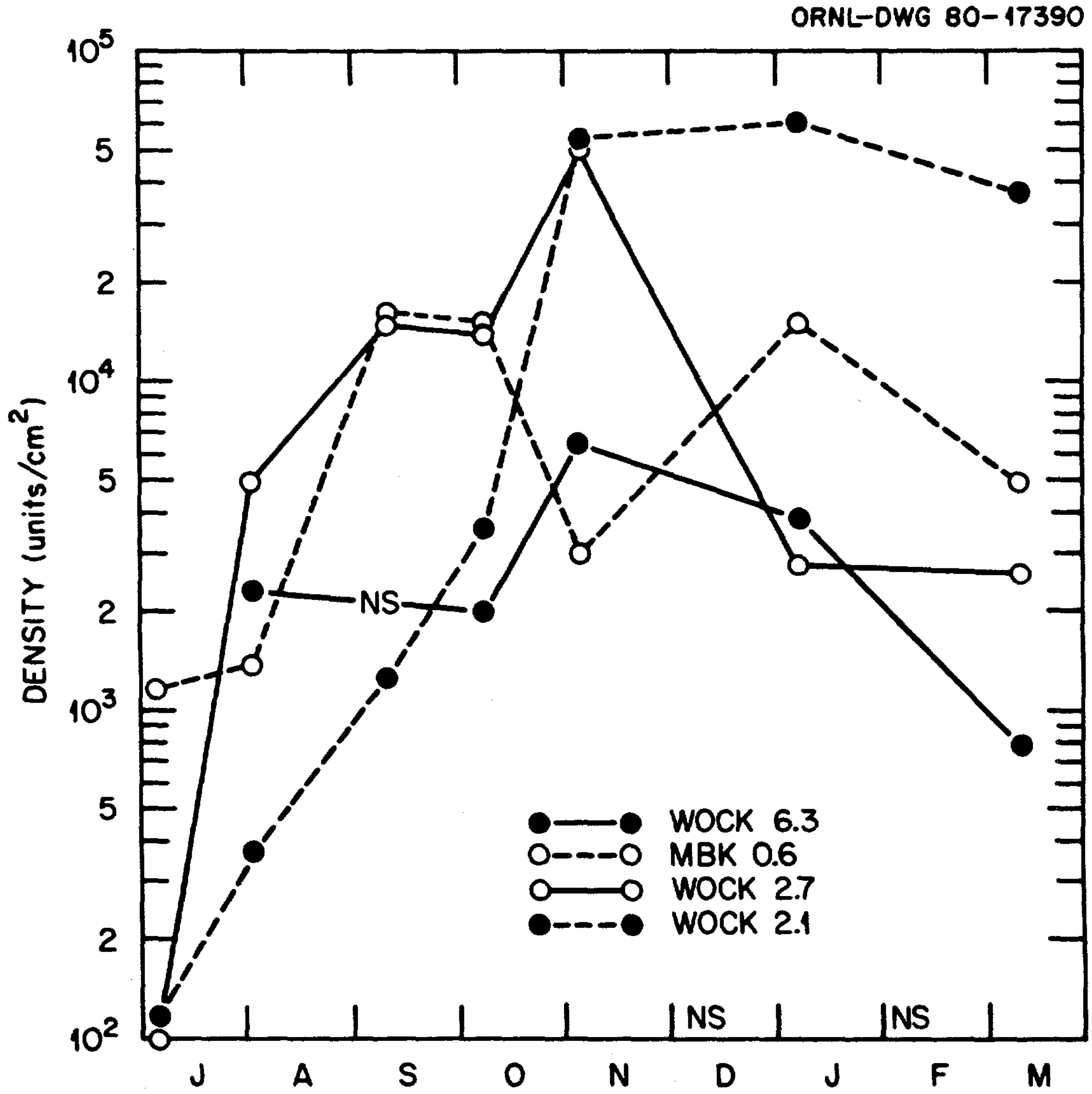

Fig. 4.2. Temporal fluctuations in the density of Chlorophyta (units/cm^2) on plexiglass slides at four sites in upper White Oak Creek watershed, July 1979-March 1980. Dates shown on the graph represent the last day of the 28-d colonization period [14 and 18 d for the August and October samples, respectively, at White Oak Creek kilometer (WOCK) 6.3]. For colonial forms, 1 colony = 1 unit. NS = no samples. MBK = Melton Branch kilometer.

two-way factorial design. Results from an analysis of variance (ANOVA) test (blocked by sampling date) revealed no significant differences between the densities of diatoms (all taxa combined) or between the densities of Chlorophyta among the four stations ($p > 0.05$ for both analyses).

Biomass

Fluctuations in periphyton biomass occurred throughout the year at all four stations (Fig. 4.3), but the magnitude of these fluctuations varied considerably between the stations. At station WOCK 6.3, for example, the fluctuations were relatively small, and peaks were not well defined. Periphyton biomass in the spring was similar to that observed in the summer at both WOCK 6.3 and MBK 0.6. At the latter site, however, a gradual increase in biomass occurred throughout the winter until early spring. The largest peaks were observed at the two sites on White Oak Creek below ORNL where maximum biomass occurred in the fall (WOCK 2.7) and spring (WOCK 2.1). Minor peaks occurred in August and May at both sites.

Differences in biomass between the stations were most obvious during the colder periods of the year. For most of the summer and again in late spring of the following year, periphyton biomass was similar at all four sites. The same statistical test (ANOVA) used to examine differences in cell counts was applied in the analysis of biomass. The test did not detect any significant differences in biomass among the four sampling sites ($p > 0.05$).

Chlorophyll a

Measurement of the chlorophyll a of periphyton provides yet another measure of abundance. The seasonal distribution of chlorophyll a was similar to that of biomass at each of the four sites. Peaks in chlorophyll a values occurred in the spring at three of the four sites. At the station on Melton Branch (MBK 0.6), however, the major peak occurred in early March and no minor peaks were observed afterward. The maximum chlorophyll a value at station WOCK 2.7 coincided with the period of maximum biomass.

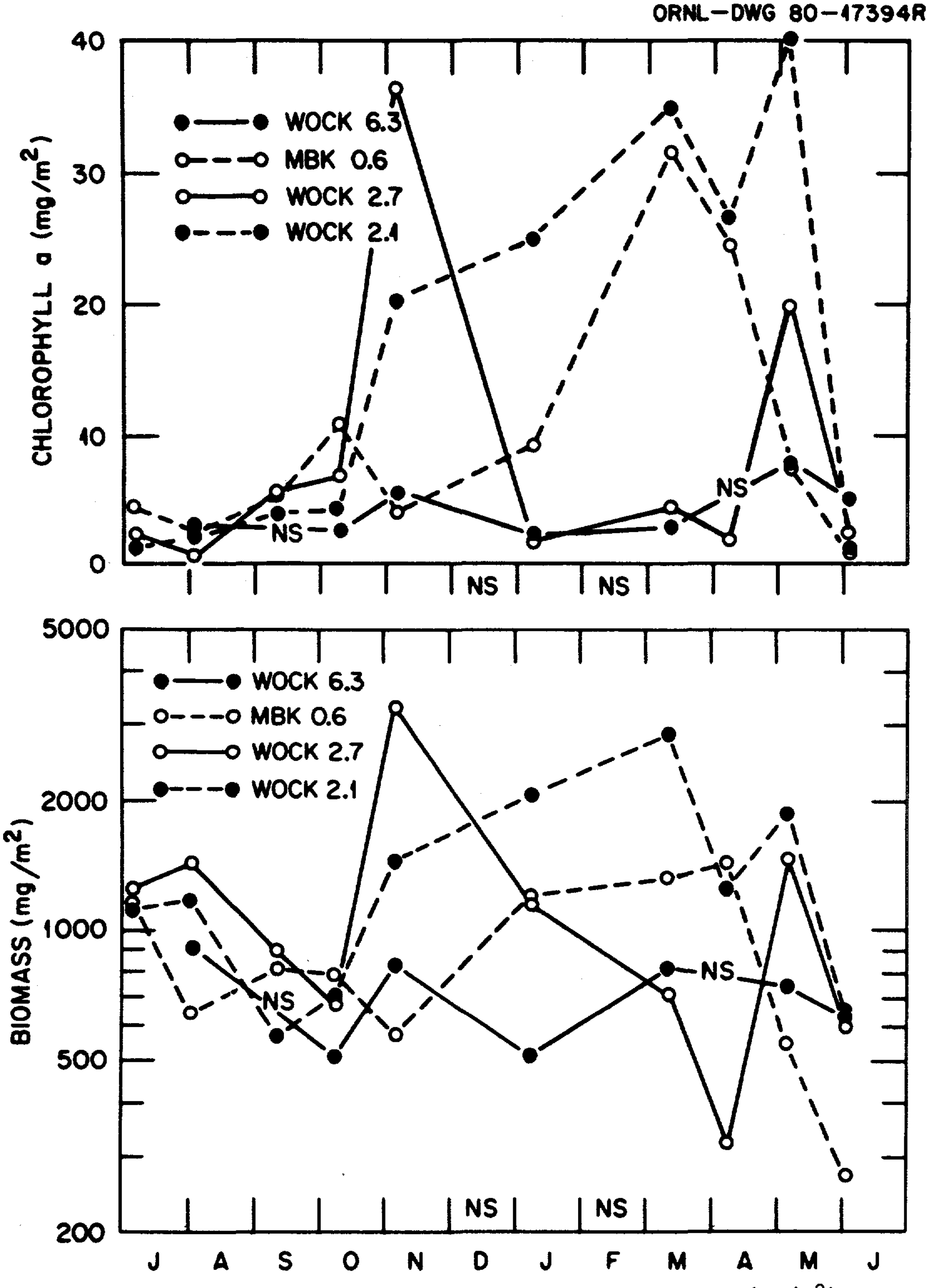

Fig. 4.3. Temporal fluctuations in chlorophyll a (mg/m^2) and biomass (mg/m^2) of periphyton on plexiglass slides at four sites in upper White Oak Creek watershed, July 1979–June 1980. Dates shown on the graph represent the last day of the 28-d colonization period [14 and 18 d for the August and October samples, respectively, at White Oak Creek kilometer (WOCK) 6.3]. For colonial forms, 1 colony = 1 unit. NS = no samples. MBK = Melton Branch kilometer.

Differences in chlorophyll a among the four sites were greatest during the winter and early spring. The values in late spring at the end of the sampling program were similar to those recorded during most of the preceding summer. A comparison of the chlorophyll a in periphyton collected from the four sites was performed using the ANOVA method described previously. No significant differences in chlorophyll a were found among the four stations ($p > 0.05$).

A ratio of biomass to chlorophyll a [the autotrophic index (AI)] has been proposed to describe the periphyton communities from natural vs degraded environments. The index was developed by Weber (1973), who found that algae usually contained from 1 to 2% chlorophyll a on a dry weight basis. Periphyton from an uncontaminated, pristine environment would consist primarily of algae, and the ratio of biomass to chlorophyll a for such a community could be less than 100. If the organic content (dissolved or particulate) of the water is elevated, however, a larger portion of the periphyton community would consist of heterotrophs (e.g., bacteria, protozoans, and fungi), the proportion of chlorophyll a would be reduced, and a higher value for the AI would be obtained.

Maximum values of the AI occurred between early May and late July at all four sampling sites (Fig. 4.4), but the peaks at stations WOCK 2.1 (AI = 840.8) and 2.7 (AI = 1729.2) greatly exceeded the maxima observed at the Melton Branch and upper White Oak Creek (control) stations. The shape of the curves depicting the temporal fluctuations in the AI at stations WOCK 2.1 and MBK 0.6 is parabolic, whereas the curves for the other stations were characterized by relatively high AI values during the winter. The shape of the curves is, to some extent, determined by the design of the sampling program (i.e., when sampling is initiated and when it is terminated). However, the occurrence of high AI values in the winter at the control station on White Oak Creek may be due to the increased transport of organic matter during storms. Such events may have a greater effect on transport in the upper regions of the watershed. Considering the magnitude of the fluctuations observed at the two sites below ORNL, it is unlikely that storm events alone could account for the high AI values observed at these sites.

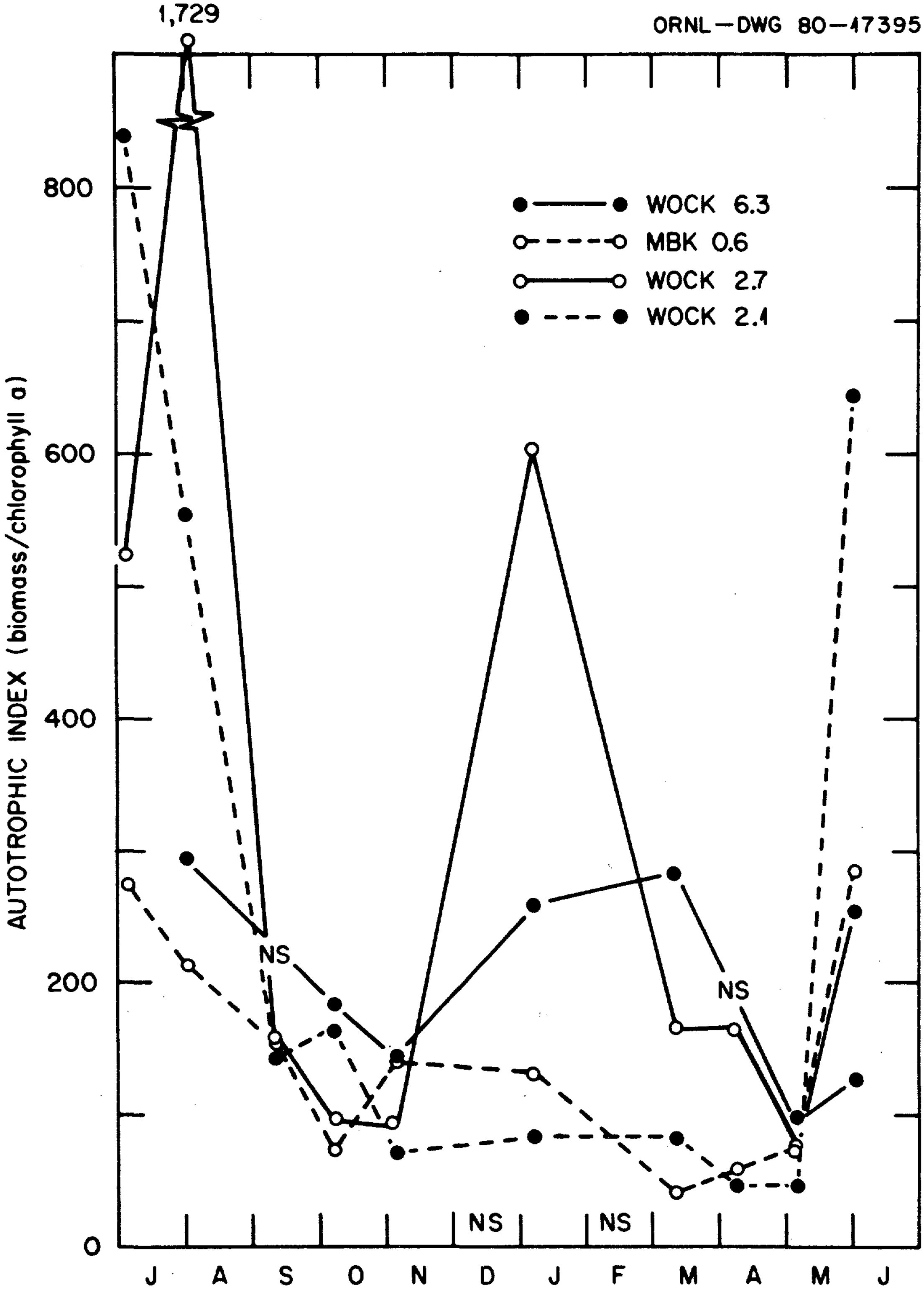

Fig. 4.4. Temporal fluctuations in the autotrophic index values (biomass to chlorophyll a ratio) for periphyton on plexiglass slides at four sites in upper White Oak Creek watershed, July 1979-March 1980. Dates shown on the graph represent the last day of the 28-d colonization period [14 and 18 d for the August and October samples, respectively, at White Oak Creek kilometer (WOCK) 6.3]. For colonial forms, 1 colony = 1 unit. NS = no samples. MBK = Melton Branch kilometer.

4.1.2 Benthic macroinvertebrates

Previous studies

Limited quantitative sampling of the benthic macroinvertebrate fauna in upper White Oak Creek watershed was conducted in 1952-53 (Krumholz 1954b) and in 1974-75 (B. G. Blaylock, unpublished data). In both studies, benthic communities in White Oak Creek below ORNL were dominated by two groups: chironomids (Diptera: Chironomidae) and tubificids (Oligochaeta: Tubificidae) (Table 4.1). Snails (Mollusca: Gastropoda) were also relatively abundant in the 1952-53 survey, and the community just below Melton Branch (WOCK 2.5) was somewhat more diverse than the benthic community in White Oak Creek above the confluence with Melton Branch. Both surveys also included sampling at control stations located above ORNL. Similar communities were found at these sites in 1953 and 1974 (Table 4.2). The high diversity of these communities, especially the high densities and diversity of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), above Oak Ridge National Laboratory (ORNL) is striking when compared to the communities that inhabit White Oak Creek below ORNL. All three orders were totally absent from the samples collected between ORNL and Melton Branch in both 1953 and 1974. The spatial distribution of the benthic communities in upper White Oak Creek during the 1979-80 survey showed an almost identical pattern.

Both of the earlier surveys also provided limited information on the communities in Melton Branch. The results from sampling conducted in 1953 indicated a diverse benthic fauna similar to that of the upper reaches of White Oak Creek and similar to that found in Melton Branch in 1975 above the point where plant effluent is discharged to the creek (Table 4.3). About 75 m below this point, the fauna was depauperate. The present study and the results of these earlier surveys suggest that a significant change in the benthic community of Melton Branch occurred between 1953 and 1974, but this change in benthic community composition and abundance was not as great as the change that must have occurred in White Oak Creek some time after operations at ORNL commenced.

Finally, a qualitative survey of the mollusk found on the DOE Oak Ridge Reservation and surrounding area was conducted in 1961

Table 4.1. Mean densities (number of individuals per 0.1 m^2) of benthic macroinvertebrates reported from previous surveys conducted in White Oak Creek between White Oak Lake and ORNL

Taxon	1953[a]				1974[b]			
	Site 28		Site 30					
	Mar.	May	Mar.	May	Aug.	Oct.	Nov.	Dec.
Coleoptera								
Elmidae	0.5							
Diptera								
Chironomidae[c]		2.2	19.4	62.6[d]	1.4	2.2	1.8	0.4
Ephemeroptera								
Caenis	0.5							
Unidentified		0.5						
Gastropoda								
Ferrisia				2.9				
Lymnaea								0.4
Menetus				0.4				
Physa				6.8				
Odonata								
Ischnura sp.							0.4	
Oligochaeta								
Tubificidae[e]	26.9	10.8	30.1	165.9[f]	0.7	1.8	5.4	3.6
Unidentified				0.4				
Tricladida								
Curtisia		0.5						

[a] Source: Krumholz (1954b), Table 72. Densities based on two Surber samples, except site 30 in May (three samples). Sites 28 and 30 were located near White Oak Creek kilometers (WOCK) 2.4 and 2.7 respectively. The confluence of Melton Branch and White Oak Creek is located at WOCK 2.5.

[b] Source: B. G. Blaylock, unpublished data. Densities based on three Surber samples taken at a site 100 m below ORNL.

[c] Reported as Tendipedidae by Krumholz (1954b).

[d] Actual densities (number of individuals per square foot) reported for the three samples were 75-100, 70, and 17. A value of 87.5 in sample 1 was used to compute the tabular value.

[e] Reported as *Tubifex* sp. by Krumholz (1954b).

[f] Actual densities (number of individuals per square foot) reported for the three samples were 100-125, 200, and 100-200. The densities used to compute the tabular value were 112.5, 200, and 150, respectively.

Table 4.2. Mean densities (number of individuals per 0.1 m^2) of benthic macroinvertebrates reported from previous surveys in White Oak Creek above ORNL

Taxon	1953[a]			1974[b]			
	Mar.	Early May	Mid-May	Aug.	Oct.	Nov.	Dec.
Amphipoda							
Gammarus sp.				2.2			
Coleoptera							
Elmidae							
Gonielmis sp.				0.7	3.6		
Optioservus sp.				0.7	2.5		0.4
Unidentified	2.5						
Others							
Anchytarsus sp.				1.8	5.0		
Ectoparia					0.4		
Helichus sp.				0.4			
Decapoda							
Cambarus sp.							1.1
Unidentified			0.5				
Diptera							
Antocha	2.5	0.5					0.7
Chaoborus sp.					0.7		
Chironomidae	4.7[c]			0.4	0.7		11.1
Limnophila sp.					0.4		
Simulium		0.5		1.1	0.4		
Tipula	0.4	0.5				1.4[d]	
Ephemeroptera							
Ameletus	2.5		8.6				
Baetis		8.1		10.4			0.7
Caenis	0.7						
Ephemera	18.3	0.5		*e*	*e*	*e*	*e*
Ephemerella	20.1	4.3	9.7	0.4	12.6		0.7
Habrophlebia		1.1					
Habrophlebiodes	3.6	2.7	12.9	*e*	*e*	*e*	*e*
Isonychia				1.4		1.1	
Paraleptophlebia				*e*	*e*	*e*	*e*
Stenonema	2.5	4.3			1.4	0.4	0.4
Gastropoda							
Goniobasis sp.				5.7	4.3		
Hydracarina							
Atractides sp.					7.5		
Unidentified	0.5						
Isopoda							
Lirceus	1.8	0.5	76.4	3.9			

Table 4.2 (continued)

Taxon	1953[a]			1974[b]			
	Mar.	Early May	Mid-May	Aug.	Oct.	Nov.	Dec.
Neuroptera							
Nigronia				0.4			
Sialis					0.4		
Odonata							
Lanthus			6.4				
Oligochaeta							
Lumbriculidae					0.4		
Tubifex	0.7		4.3				
Plecoptera							
Acroneuria		2.7	6.4	0.7	2.5	0.4	
Alloperla	4.3			0.4			0.4
Isoperla		1.6		*e*	*e*	*e*	*e*
Leuctra sp.					2.8[f]		
Nemoura sp.				*e*	*e*	*e*	*e*
Peltoperla sp.					0.7		
Tricoptera							
Agapetus							
Cheumatopsyche sp.		9.1		1.1	2.5	7.9	7.9
Diplectrona sp.				1.8			
Glossosoma sp.				0.7			0.4
Hydropsyche sp.				1.1	0.7	1.8	
Lepidostoma sp.				0.4			
Neophylax	23.7	5.4		*e*	*e*	*e*	*e*
Psilotreta	15.1	8.6		1.4			
Psychomyia sp.					0.4		
Rhyacophila ledra						0.7	
Unidentified	7.4	65.6	9.7				
Tricladida							
Curtisia				1.8			

[a]Source: Krumholz (1954b), Table 73. Densities based on three Surber samples in March (stations 60, 60a, and 61), two samples in early May (stations 60 and 62) and one sample in late May (station 60). The sampling sites were located in a 30-m reach of the creek north of Bethel Valley Road.

[b]B. G. Blaylock, unpublished data. Densities based on three Surber samples taken each month at a site 300 m north of Bethel Valley Road.

[c]Reported as Tendipedidae.

[d]Reported as *Tipula abdominalis*.

[e]Genus was listed in original table of species densities, but no densities were reported.

[f]Includes individuals identified as Leuctridae.

Table 4.3. Mean densities (number of individuals per 0.1 m^2) of benthic macroinvertebrates reported from previous surveys in Melton Branch

Taxon	1952[a]		1974-75[b]			
			MB-1		MB-2[c]	
	July	Dec.	Jan. 1975	Feb. 1975	Dec. 1974	Feb. 1975
Coleoptera[d]						
Elmis	4.3	4.3				
Helichus	3.2[e]	5.4[e]				
Decapoda						
Cambarus sp.			0.4			
Diptera						
Chironomidae	5.4[f]	5.4[f]	0.7	0.4		
Tipula sp.			1.1			
Pseudolimnophila sp.				0.4		
Hexatoma sp.					0.4	
Ephemeroptera						
Ameletus	2.2		0.4	0.7		
Baetis		4.3		0.4		
Ephemera	1.1	7.5	0.4	0.7		
Ephemerella		1.1				
Habrophlebiodes sp.				0.4		
Stenonema	12.9	30.1	*g*	*g*	*g*	*g*
Isopoda						
Lirceus	1.1	10.8				
Neuroptera						
Nigronia				0.4		
Sialis				0.4		
Oligochaeta						
Lumbricidae			1.4	1.1		
Plecoptera						
Nemoura sp.				0.4		
Acroneuria sp.			1.8	0.4		
Unidentified Capniidae		7.5				
Tricladida						
Curtisia		7.5				
Tricoptera						
Hydropsychidae						
Cheumatopsyche sp.			0.4			
Diplectrona sp.				0.4		
Unidentified	31.2	53.8				

Table 4.3 (continued)

Taxon	1952[a]		1974-75[b]			
			MB-1		MB-2[c]	
	July	Dec.	Jan. 1975	Feb. 1975	Dec. 1974	Feb. 1975
Others						
Neophylax sp.				0.7		0.4
Rhyacophila sp.				0.7		

[a]Source: Krumholz (1954b), Table 74. Samples (no. taken on each date not reported) were collected with a Surber sampler at station 44, located near MBK 0.1.

[b]Source: B. G. Blaylock, unpublished data. Densities based on three Surber samples taken at each site. Stations MB-1 (control) and MB-2 were located 200 m above and 75 m below the chromate discharge point near MBK 1.5.

[c]Samples were also taken in January but no organisms were collected.

[d]The genera *Microcylloepus, Optioservus, and Stenelmis* (Insecta: Coleoptera) were included in the original table of species densities at MB-1 and MB-2 in the 1974-75 study, but no densities were given.

[e]Includes both larvae and adults.

[f]Reported as Tendipedidae.

[g]Genus included in original table but no densities given (see footnote *d*).

(H. W. Van der Schalie and J. Burch, University of Michigan, unpublished data). Their results indicated the existence of several species in two of the small tributaries of White Oak Creek that originate on the southwest slope of Chestnut Ridge (Table 4.4). No mollusks were reported, however, in several other tributaries of White Oak Creek north of Bethel Valley Road, and none were found at 20 additional sites in White Oak Creek watershed south of Bethel Valley Road, including several tributaries to Melton Branch.

Taxonomic composition

The composition of the benthic macroinvertebrate communities during the 1979-80 survey was similar to that described previously (Krumholz 1954b; B. G. Blaylock, unpublished data). Chironomids alone comprised 97.5 and 94.1% of all the organisms collected at stations WOCK 2.7 and 2.1 respectively. Nonchironomid dipterans, primarily Empipidae, accounted for an additional 1.9 and 1.5% of the fauna respectively. The major difference between the communities at the two sites was found in the relative abundance of *Stenelmis* (Coleoptera: Elmedae). Forty individuals (3.5% of the total organisms) were collected on eight of nine sampling dates at station WOCK 2.1; none were found in the 27 samples taken at WOCK 2.7.

Although a greater diversity of taxa was found in Melton Branch (Table 4.5), chironomids were still the most abundant taxon, accounting for 80.1% of the organisms collected at station MBK 0.6. The relative abundance of Coleoptera was 10.9%, and two genera of the family Elmidae, *Stenelmis* and *Optioservus*, comprised 92.8 and 5.3%, respectively, of the coleopterans at this site. Although no Trichoptera were found, four genera of Ephemeroptera (most of which were *Baetis*) and two genera of Plecoptera were found. The relative abundance of these two groups, however, was low (1.9 and 0.2% respectively).

Maximum taxonomic diversity was found at the upstream (control) site on White Oak Creek. Ephemeroptera (ten genera) was the dominant group, comprising 41.0% of the organisms collected at this site. Plecoptera (four genera) accounted for 18.7% of the fauna. In contrast to the other

Table 4.4. Mollusk species collected during a 1961 survey from sites in upper White Oak Creek watershed and from two tributaries of the Clinch River near the mouth of White Oak Creek (Van der Schalie and Burch, unpublished data)

Numbers refer to sampling sites as identified in the original survey

Species	White Oak Creek watershed at or above Bethel Valley Road[a]			Tributaries of Clinch River near mouth of White Oak Creek[b]	
	1	64,111	112	54	205
Gastropoda					
Lymnaeidae					
Lymnaea exigua		X			
L. obrussa	X			X	
Physidae					
Physa crocata		X	X		
P. heterostropha		X			
P. integra				X	
Pleuroceridae					
Goniobasis clavaeformis			X		X
Pelecypoda					
Sphaeriidae					
Pisidium casertanum		X			X
P. punctifera		X			X

[a]See Fig. 2.1. Site 1 = White Oak Creek at Bethel Valley Road; site 64,111 = tributary of White Oak Creek which is located ∿2.2 km east of Route 95 (sites 64 and 111 were located at Bethel Valley Road and 90 km above the road respectively); site 112 = tributary of White Oak Creek at Bethel Valley Road. The stream is located ∿1.5 km east of Route 95.

[b]Site 54 = tributary of Clinch River ∿30 m above the confluence which is located near Clinch River kilometer (CRK) 32.2; site 205 = Ish Creek (see Fig. 2.1) ∿500 m above the confluence which is located near CRK 30.8.

Table 4.5. Comparison of the mean number of taxa per sample and total taxa at four sampling sites in upper White Oak Creek watershed, March 1979-February 1980

	Sampling location[a]			
	WOCK 6.3[b]	WOCK 2.7	WOCK 2.1	MBK 0.6[c]
Mean number of taxa per sample	8.6	1.9	2.5	2.7
Range	2-18	1-3	1-6	2-8
Total number of taxa collected	44	9	14	25

[a]See Fig. 2.1-1.

[b]White Oak Creek kilometer 6.3.

[c]Melton Branch kilometer 0.6.

sites, chironomid and coleopteran abundance was relatively low (15.1 and 1.4% respectively). Only two elmids identified as *Stenelmis* were found; most (32 of 35, or 91%) were *Optioservus*. Finally, the relative abundance of oligochaetes was considerably higher (18.8%) at the control station than the other sites. This estimate is somewhat misleading since more than 68% of the oligochaetes were found in only two samples. Such a distributional pattern is often encountered at sites where habitat heterogeneity is high.

Temporal abundance and distribution

The distribution of total benthic macroinvertebrate densities from March 1979 through February 1980 exhibited a similar pattern at all four sample sites (Fig. 4.5). The occurrence of very low densities (ten or less individuals per 0.1 m^2) at the control station on White Oak Creek accounts for much of the similarity in the temporal density patterns between this site and those located below ORNL. In all likelihood, this pattern is atypical and was the result of no flow in the creek during much of June and July (Sect. 2.1). Densities were high in June prior to the noflow period but decreased sharply in the samples taken after this period. In a stream with a rich diversity of taxa, emergence alone cannot explain such a dramatic decline in density. Mayfly species, for example, emerge at different times, from the late winter or spring through fall. The duration of the emergence period may also vary among species. Since the decline was observed for all taxa, emergence seems an unlikely explanation. In addition, total densities at this site were higher than the other sites during most of the spring and again in early fall (at the new site located approximately 400 m upstream; see Sect. 3.1). The sharp decline observed in July and August seems inconsistent with the estimates of abundance before and after this period.

The decline in total density observed during the summer at the three sites below ORNL could be attributed to the emergence of chironomids in the spring (Fig. 4.6), as evidenced by the large number of pupae in the samples collected on April 23. The decline, however, was not as sharp as that observed at station WOCK 6.3, further suggesting that the decline in

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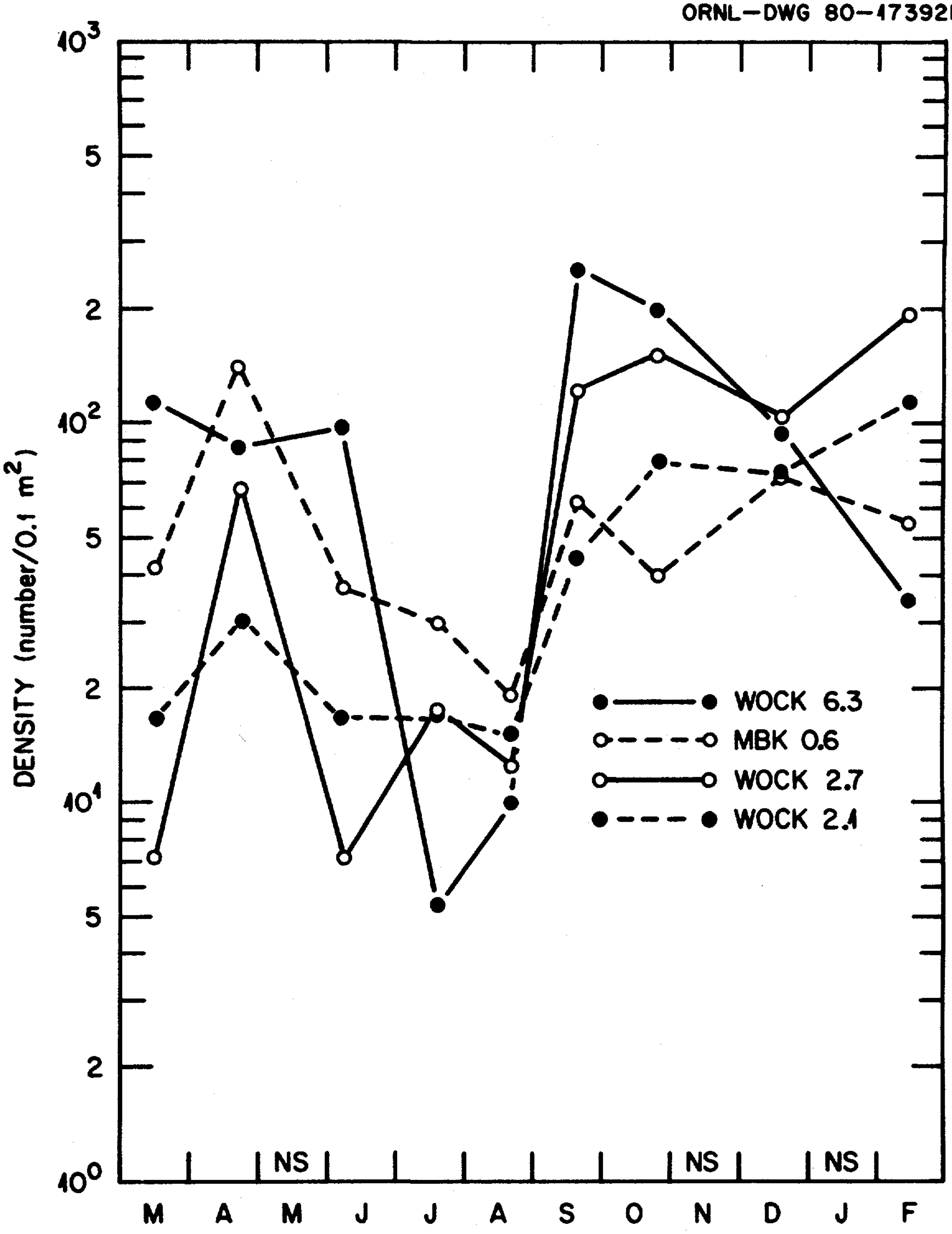

Fig. 4.5. Temporal fluctuations in total benthic macroinvertebrate densities (all taxa combined) at four sites in upper White Oak Creek watershed, March 1979-February 1980. The confluence of White Oak Creek and Melton Branch is located at WOCK 2.5. NS = no samples taken. MBK = Melton Branch kilometer.

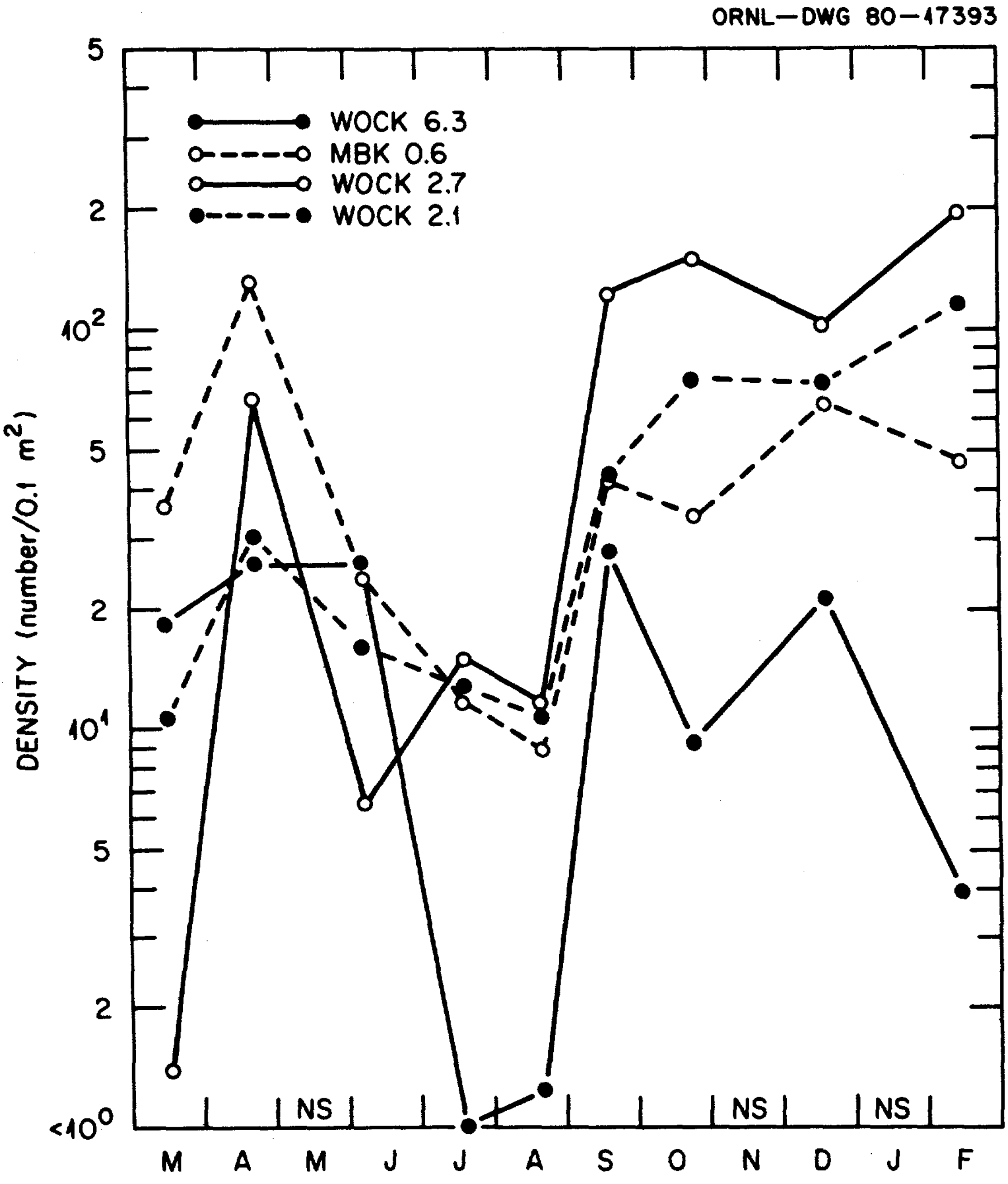

Fig. 4.6. Temporal fluctuations in Chironomidae at four sites in upper White Oak Creek watershed, March 1979-February 1980. The confluence of White Oak Creek and Melton Branch is located at White Oak Creek kilometer (WOCK) 2.5. NS = no samples taken. MBK = Melton Branch kilometer.

abundance at this latter site was not the result of emergence. Peak chironomid densities occurred during the fall and winter at stations WOCK 2.7 and 2.1, and the temporal trends in abundance were almost identical at these sites. Chironomid densities at station MBK 0.6 were highest in the spring, but the pattern in abundance was similar to that observed at the two sites on White Oak Creek below ORNL. Information on species composition of the chironomid communities, as determined from the examination of selected samples from the four sites in upper White Oak Creek watershed, is presented in Appendix C.

Temporal fluctuations in the density of the most abundant non-chironomid taxa are shown in Fig. 4.7. The abundance of *Stenelmis* exhibited two peaks, separated by about three months, at stations WOCK 2.1 and MBK 0.6. The peaks, however, occurred earlier at the latter site, possibly because of higher water temperatures (Fig. 2.2). High densities of mayflies were only characteristic of the benthic communities above ORNL. The more common genera exhibited maxima at different times of the year. For example, maximum densities of *Baetis* (17.6/0.1 m^2) occurred in June (a similar peak also occurred at the Melton Branch site), whereas peak densities of *Ephemerella* (46.3/0.1 m^2) and *Paraleptophlebia* (81.4/0.1 m^2) occurred in February and September respectively. The low densities of both of these genera in spring may, in part, be the result of differences in habitats between the two sampling sites (WOCK 6.3 before and WOCK 6.7 after September). Although temporal abundance patterns at the control station are somewhat ambiguous as a result of the occurrence of a no-flow period and the necessity to move the station upstream, it is obvious that taxa abundant in upper White Oak Creek are not found below ORNL and are found in reduced numbers in Melton Branch.

Spatial distribution

The benthic communities at the four stations in upper White Oak Creek were compared using the Bray-Curtis dissimilarity index (Sect. 3.3). The greatest dissimilarity (0.864) was found between the community at the control station above ORNL (WOCK 6.3) and the community at station WOCK 2.7, located below ORNL but above the confluence of White Oak Creek

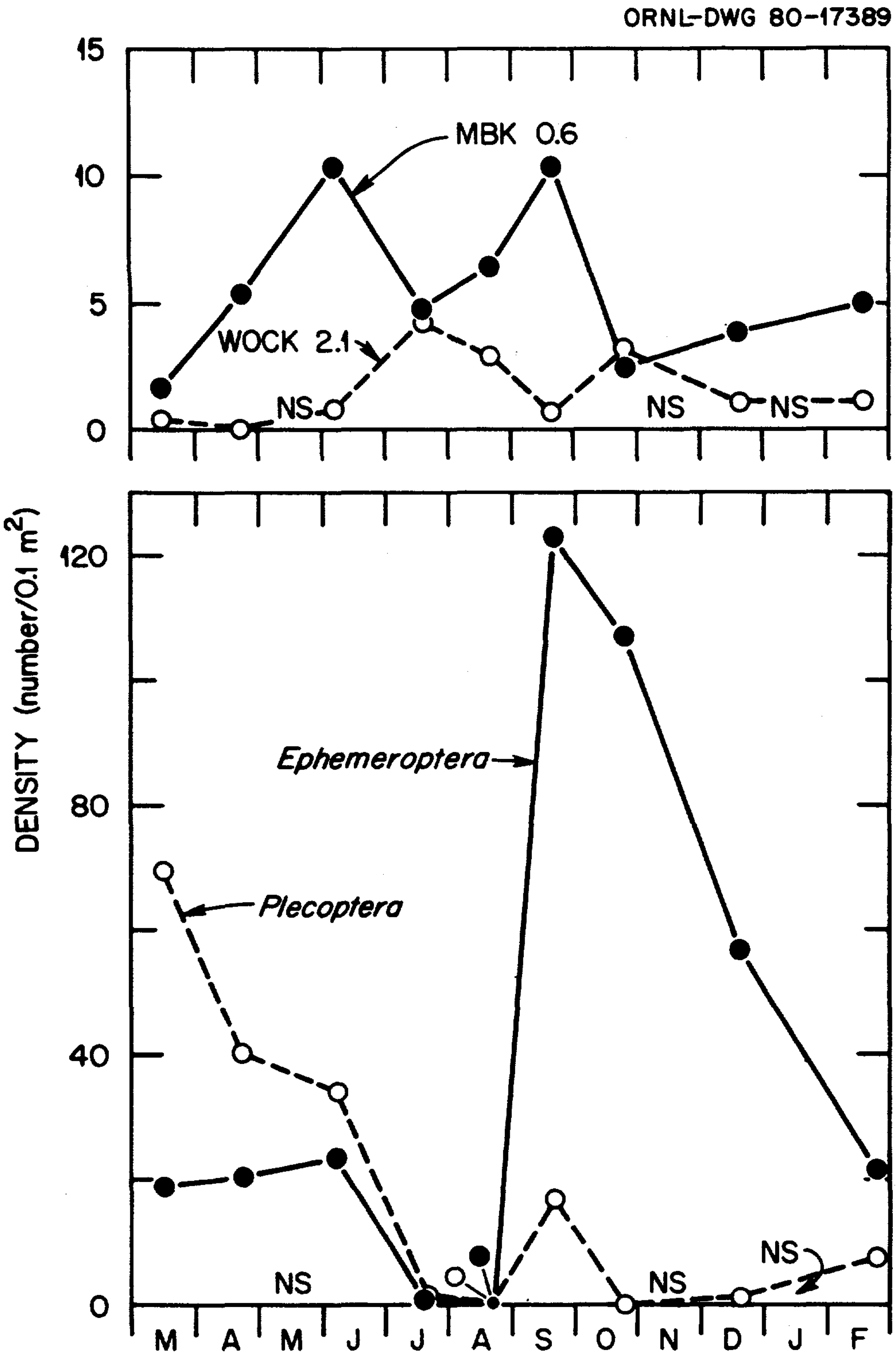

Fig. 4.7. Temporal fluctuations in the densities of selected taxa at three sites in upper White Oak Creek watershed, March 1979–February 1980. Densities of *Stenelmis* (Coleoptera: Elmidae) are shown at the top, and densities of mayflies (Ephemeroptera) and stoneflies (Plecoptera) at station White Oak Creek kilometer (WOCK) 6.3 are shown on the bottom. The confluence of White Oak Creek and Melton Branch is located at WOCK 2.5. NS = no samples taken. MBK = Melton Branch kilometer.

and Melton Branch (Table 4.6). The mean coefficients for the control station and each of the other two stations (WOCK 2.1 and MBK 0.6) were also high (>0.80). The high degree of dissimilarity between the control site and each of the other sites is not surprising. The benthic communities at the three sites located below ORNL consist primarily of chironomids, whereas a substantially greater diversity of taxa, particularly genera of the orders Ephemeroptera, Plecoptera, and Tricoptera, was found above ORNL.

Chironomid densities at the four sites were compared using a univariate analysis of variance. Densities at station WOCK 6.3 were significantly lower ($p < 0.001$) than the densities at each of the other sites, but a trend in the opposite direction was observed for oligochaetes (Table 4.7). Densities of the latter were surprisingly low at the three sites below ORNL (stations WOCK 2.7, 2.1, and MBK 0.6) and never exceeded 0.7 organisms per 0.1 m^2 on a given date.

Previous surveys of the benthic fauna in White Oak Creek below ORNL reported higher densities of oligochaetes than were observed during the present survey (Table 4.1). The low densities in the samples collected during the latter survey reflect the actual abundance of oligochaetes at the various sampling sites. That is, the results were not biased by the fact that the samples were processed at different laboratories (Sect. 3.1). The same personnel and similar procedures were used at both facilities. Moreover, samples collected at stations WOCK 1.1 and 0.2, which were also processed at ORNL, had densities similar to those found at station WOCK 6.3. These observations suggest that oligochaetes, although small, were not overlooked during the process of separating the organisms from the debris (i.e., detritus, gravel, sand, etc.) in the laboratory. Although no adequate explanation can be given for the low densities at WOCK 2.7, 2.1, and MBK 0.6, it is doubtful that such results were due to differences in substrate between these stations and the control site, since attempts were made to minimize differences in substrate among the four sites (Sect. 3.1).

Table 4.6. Comparison of the mean coefficient of dissimilarity (± 1 standard error) for the benthic macroinvertebrate communities between all station pairs in upper White Oak Creek watershed

Tabular values were derived from coefficients computed separately for each sampling date, March 1979–February 1980. Means that do not have the same letter in their superscript are significantly different (p <0.05).

	WOCK 6.3[a]	WOCK 2.7	WOCK 2.1	MBK 0.6[b]
WOCK 6.3		0.864[a] (0.031)	0.819[a] (0.032)	0.825[a] (0.027)
WOCK 2.7			0.342[b] (0.075)	0.548[c] (0.060)
WOCK 2.1				0.408[b] (0.037)
MBK 0.6				

[a]White Oak Creek kilometer 6.3.

[b]Melton Branch kilometer 0.6.

Table 4.7. Comparison of the geometric mean densities of chironomids and oligochaetes at the four sampling sites in upper White Oak Creek watershed

Values not connected by the same line are significantly different (p <0.00)

	WOCK 6.3[a]	WOCK 2.7	WOCK 2.1	MBK 0.6[b]
Chironomidae	13.55	98.77	40.34	51.78
Oligochaeta	4.72	0.08	0.04	0.02

[a]White Oak Creek kilometer 6.3.

[b]Melton Branch kilometer 0.6.

4.1.3 Ichthyoplankton

A total of 46 ichthyoplankton samples were taken on 23 sampling dates between March 13 and September 24, 1979. Sample volumes averaged 66.4 m^3 at WOCK 2.1 (range: 5.3 to 107.4 m^3), and sampling velocities generally ranged from 30 to 64 cm/s.

No fish eggs and only three larvae were collected at station WOCK 2.1. A single, 5-mm total lentgh (TL) *Lepomis* larvae was found on May 14, and cyprinid larvae were collected on May 30 and June 5 (8 and 7 mm TL respectively).

These samples indicate that relatively little spawning activity occurs in the White Oak Creek drainage above White Oak Lake. Sample volumes, velocities, and frequencies that were adequate to detect spawning peaks at the other sampling stations caught few ichthyoplankton at WOCK 2.1. However, it has been established by this sampling program that some level of fish spawning does occur above White Oak Lake, since the net used at WOCK 2.1 was not used at any other station (thus precluding the possibility that larvae collected at WOCK 2.1 were carried over in the net from other stations).

The fish larvae collected at station WOCK 2.1 could have originated from various uncontaminated water bodies above White Oak Lake. The *Lepomis* larvae, for example, may have drifted downstream from a small pond (Swan Pond) located just south of Bethel Valley Road and northeast of the Building 4500 complex at the east end of ORNL. The pond, which was created by damming a small tributary of White Oak Creek near WOCK 4.2, contains bluegill (*Lepomis macrochirus*) (B. G. Blaylock, personal communication). The cyprinid larvae could also have originated from this pond or from small tributary streams in the drainage (e.g., West Branch near WOCK 2.9).

4.1.4 Fishes

The fish community in White Oak Creek and Melton Branch was sampled by electroshocking in late November 1979, and again in late January 1980. No fish were found in the 50-m study section of Melton Branch (station

MBK 0.6) and White Oak Creek near WOCK 2.7 on either date. Electroshocking an additional 20 to 85 m of the stream at these sites on the two sampling dates was also unsuccessful. Fish were found in White Oak Creek just above White Oak Lake (station WOCK 2.1) and at the control station north of Bethel Valley Road near WOCK 6.7 (Table 4.8).

The communities at the two stations above and below ORNL were markedly different; none of the species collected were common to both sites. The three species collected at the upper station are common inhabitants of lotic environments. The blacknose dace is typically abundant in very small streams, and the stone roller, which is found in waters ranging from small streams to large rivers, is the most widespread and abundant species in Tennessee (D. A. Etnier, unpublished data). The community at station WOCK 2.1 consisted of two species (mosquitofish and bluegill) that are abundant in White Oak Lake. Their high abundance above the lake in late fall and their low abundance in the winter seem to indicate that the community at this site may have a strong seasonal component attributable to upstream movement from the lake. All the bluegill in the two collections were small (mean total length: 54 mm; range: 47 to 64 mm) and were probably the young-of-the-year.

Extensive sampling of the fish populations in upper White Oak Creek watershed was not required to demonstrate that considerable differences (in both composition and abundance) exist between the communities above and below ORNL. Whether some small resident populations occurred at the three lower sites could not be determined. The absence of fish in the collections from two of the three sites and the occurrence of only two cyprinid larvae in the ichthyoplankton at station WOCK 2.1 (which may have drifted downstream from tributaries not affected by ORNL operations) suggest that population densities below ORNL are very low and that spawning is limited.

Table 4.8. Number of fishes (adults and juveniles combined) collected by electroshocking a 50-m reach[a] of White Oak Creek near stations White Oak Creek kilometer (WOCK) 6.7 and WOCK 2.1 on November 20, 1979, and January 29, 1980

Species	Sampling site			
	WOCK 6.7		WOCK 2.1	
	Nov.	Jan.	Nov.	Jan.
Campostoma anomalum (Stone roller)	17	11		
Cottus carolinae (Banded sculpin)	1			
Rhinichthys atratulus (Blacknose dace)	12	8		
Gambusia affinis (Mosquitofish)			102	3
Lepomis macrochirus (Bluegill)			12	1

[a]Because of low fish densities, a 100-m reach was sampled at station WOCK 2.1 in January.

4.2 WHITE OAK LAKE

4.2.1 Phytoplankton

Previous studies

The phytoplankton community in White Oak Lake has been investigated in several studies conducted between 1950 and 1973. Unfortunately, the historical record of the phytoplankton populations in the lake is incomplete because of the methods that were employed and/or the limited quantitative sampling that was done in these studies. As a result, changes that may have occurred over the past 30 years (i.e., shifts in species composition and abundance) cannot be identified with any certainty. For example, results from the 1979-80 survey indicate that some genera (e.g., *Scenedesmus* and *Chlamydomonas*) reach very high densities at certain times of the year. These same genera, however, were not reported as abundant in previous surveys (Krumholz 1954b; Bradshaw 1973, unpublished data). In both of these studies, phytoplankton abundance, in general, was considerably lower than that found in the present survey.

These differences are most likely the result of the methods employed in the various surveys. In the two earlier studies, the samples were filtered through a No. 20 mesh (76-μm) net/bucket, and only the larger net plankton would have been retained. Thus, the abundance of small forms, including unicellular flagellates (*Chlamydomonas*) and small colonial green algae (*Scenedesmus*) would be underestimated. In the present study, these smaller algae (nannoplankton) were the dominant group in the lake.

Qualitative surveys of the phytoplankton in the lake were conducted from June to September 1956 (Lackey 1957) and in mid-July 1973 (Andrews 1973). The latter study resulted in a list of the more common net plankton species in the lake, but samples were only taken near the east shore on a single date. The dominant forms were three neustonic species of *Euglena*. Using methods similar to those described in Sect. 3.1, Lackey (1957) sampled the phytoplankton populations in White Oak Lake and the lower Clinch River prior to completion of the Melton Hill Dam (gates were closed May 1, 1963). Typical blooms that occurred in White Oak Lake during the summer of 1956 were *Chlamydomonas* in late July (704 cells/ml); *Oscillatoria* sp. and *Navicula* spp. in mid-August (1888 and 2336 cells/ml respectively), and *Chlorella pyrenoidosa* in late August (14,600 cells/ml) (Lackey 1957, Table II). Because the lake had a surface area of only 0.4 ha in the summer of 1956, and because sampling sites and frequency were not described, no conclusions can be reached regarding the shifts in phytoplankton composition and abundance that might have occurred between 1956 and the present.

Mats of filamentous algae have apparently always existed on the bottom of White Oak Lake. Krumholz (1954b) reported that *Spirogyra* was the most abundant genus and frequently covered the entire shallow upper end of the lake. Also abundant was *Oscillatoria*, patches of which often broke loose from the bottom and floated to the surface during periods of intense sunlight and high photosynthetic rates. A filamentous diatom, *Melosira*, was observed floating free in the lake in the spring. Lackey (1957) noted that when the lake level was low, vast mats of blue-green algae covered the mud in some areas. In July 1973, macroscopic filamentous mats of algae were principally *Spirogyra ellipsospora*, *Oedogonium* sp., and *Hydrodictyon reticulatum* (Andrews 1973).

Taxonomic composition

Thirty-eight of the 68 phytoplankton genera (56%) identified from White Oak Lake were Chlorophyta (Appendix B-1). This group, which composes less than 25% of the phytoplankton community in the river, accounted for about 93% of all the phytoplankton collected from White Oak Lake during the sampling program (Fig. 4.8). Although 14 genera of diatoms (Chrysophyta: Bacillariophyceae) were identified from the lake, their relative abundance was less than that of all other major groups except the Pyrrophyta. The latter group was only found on two dates, and, on each date, the density was only two cells per ml.

Seasonal distribution and abundance

Three major growth pulses were exhibited by the phytoplankton population in White Oak Lake (Fig. 4.9), and the dominant group in each was the Chlorophyta. Maximum densities occurred during the spring pulse which consisted primarily of *Scenedesmus* (Chlorophyta: Chlorococcales)

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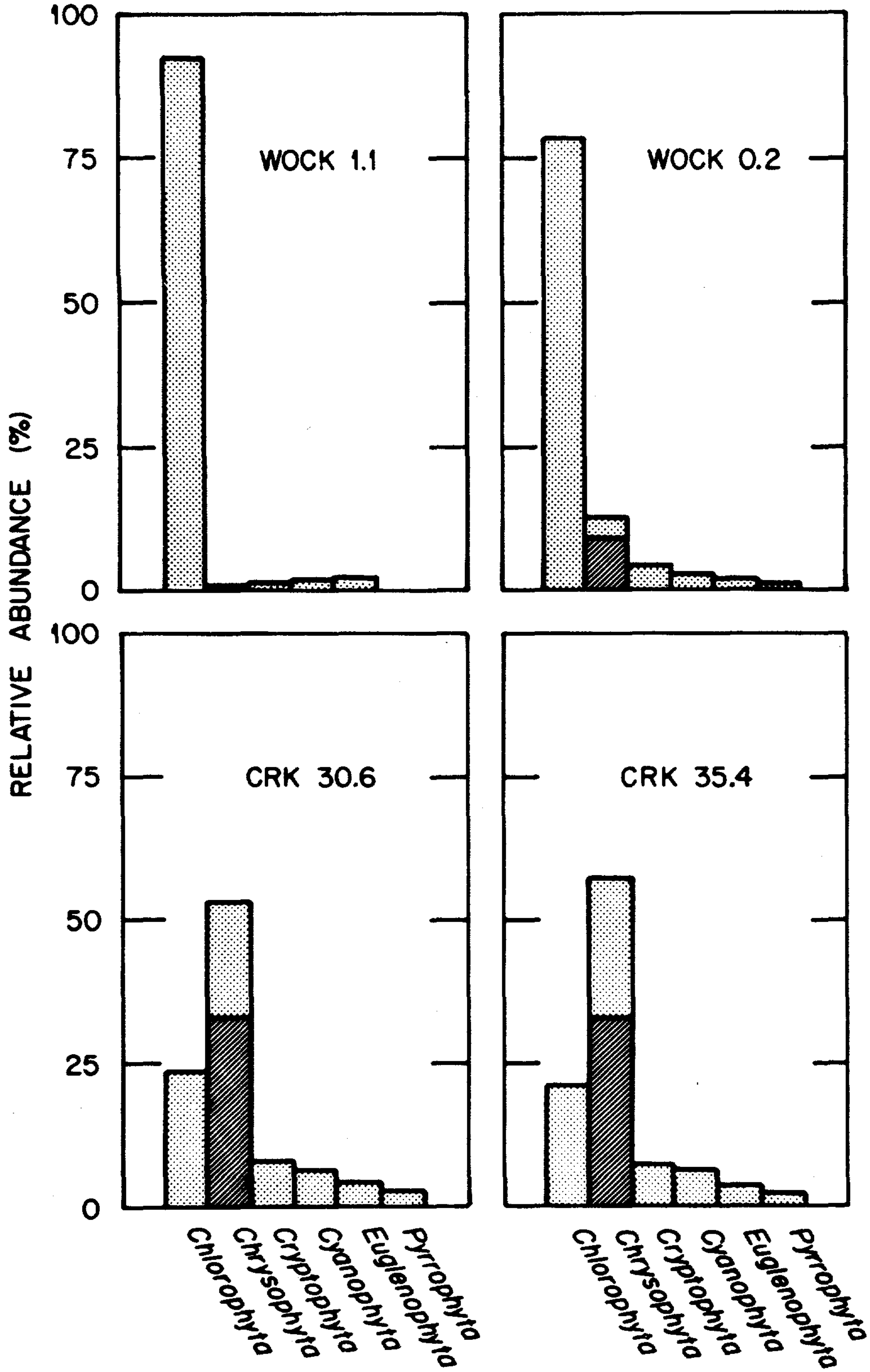

Fig. 4.8. Relative abundance of the six major phytoplankton groups in White Oak Lake [White Oak Creek kilometer (WOCK 1.1)], White Oak Creek embayment (WOCK 0.2), and two sites in the Clinch River [Clinch River kilometer (CRK)]. Percent abundance is based on the total number of phytoplankton collected at each site over the entire sampling period. Cross-hatching indicates the relative abundance of diatoms (Chrysophyta: Bacillariophyceae).

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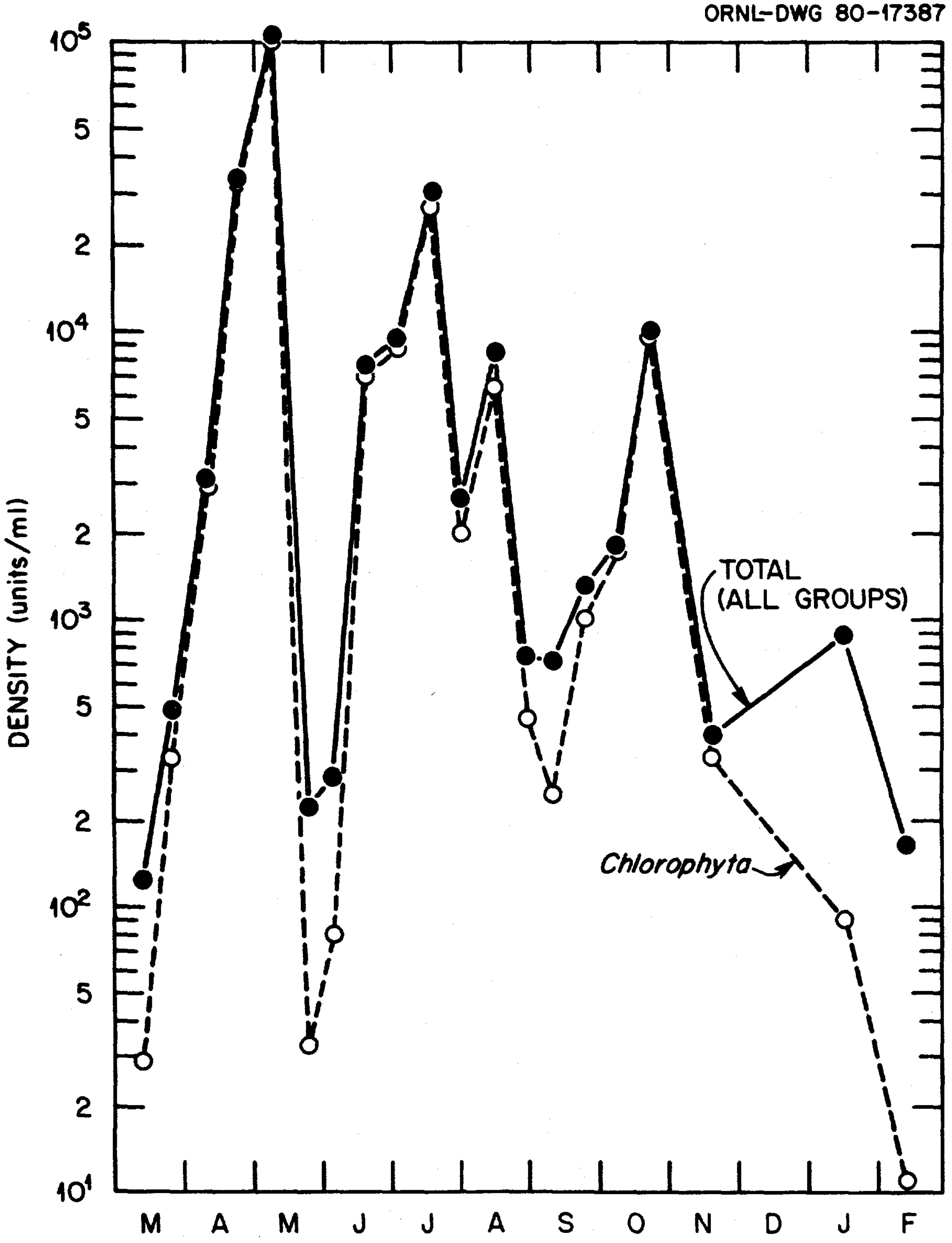

Fig. 4.9. Comparison of the temporal fluctuations in the density (units/ml) of total phytoplankton (all taxa combined) and Chlorophyta at station White Oak Creek kilometer (WOCK) 1.1 in White Oak Lake, March 1979-February 1980. For colonial forms, 1 colony = 1 unit. No samples were taken in December.

and unidentified chlorococcales (Fig. 4.10). These two taxa together made up more than 80% of the total cell numbers at this time. It should be noted that *Scenedesmus* is a colonial green alga, and each colony was counted as a single unit. Since the number of cells per colony was either four or eight at this time, the actual cell density was considerably higher. Flagellated unicellular algae, primarily *Chlamydomonas* and *Chlorogonium* (Chlorophyta: Volvocales), were also abundant during the spring pulse (Fig. 4.10).

Although the major peak in Chlorophyta abundance occurred in the spring, other groups exhibited only minor pulses at this time (Fig. 4.11). The small peak in Cyanophyta abundance was the result of an increase in density of *Dactylococcopsis* from 19 colonies/ml in late April to 486 colonies/ml in early May. The small Euglenophyta pulse was also dominated by a single genera, *Cryptoglena,* which reached a density of 405 cells/ml. This genus was not found in the samples taken in late April.

The other two growth pulses, which occurred in mid-summer and fall, were also dominated by the Chlorophyta. The same genera (with approximately the same relative abundance) that contributed to the spring pulse made up the majority of the phytoplankton in the fall pulse. The mid-summer peak, on the other hand, consisted of relatively high densities of two genera that were either not found (*Schroederia*) or were much less abundant (*Actinastrum*) at other times of the year (Fig. 4.10). Such a successional pattern within the Chlorophyta may be related to seasonal changes in water temperature. Certain species (e.g., *Scenedesmus*) may be able to grow and reproduce over a wide range of temperatures, whereas optimal conditions for others, such as *Schroederia* and *Actinastrum,* may exist only when near-maximum temperatures occur (Fig. 2.3).

The major pulse of Cyanophyta and Euglenophyta occurred in mid-July, and another smaller pulse was observed approximately four weeks later (Fig. 4.11). In both groups, the dominant genera were not those that were found during the initial pulse in the spring. For example, the two mid-summer peaks in blue-green abundance were due to high densities of the filamentous alga, *Merismopedia* (1508 and 795 filaments/ml in July and August respectively). The dominant Euglenophyta genus in mid-July was

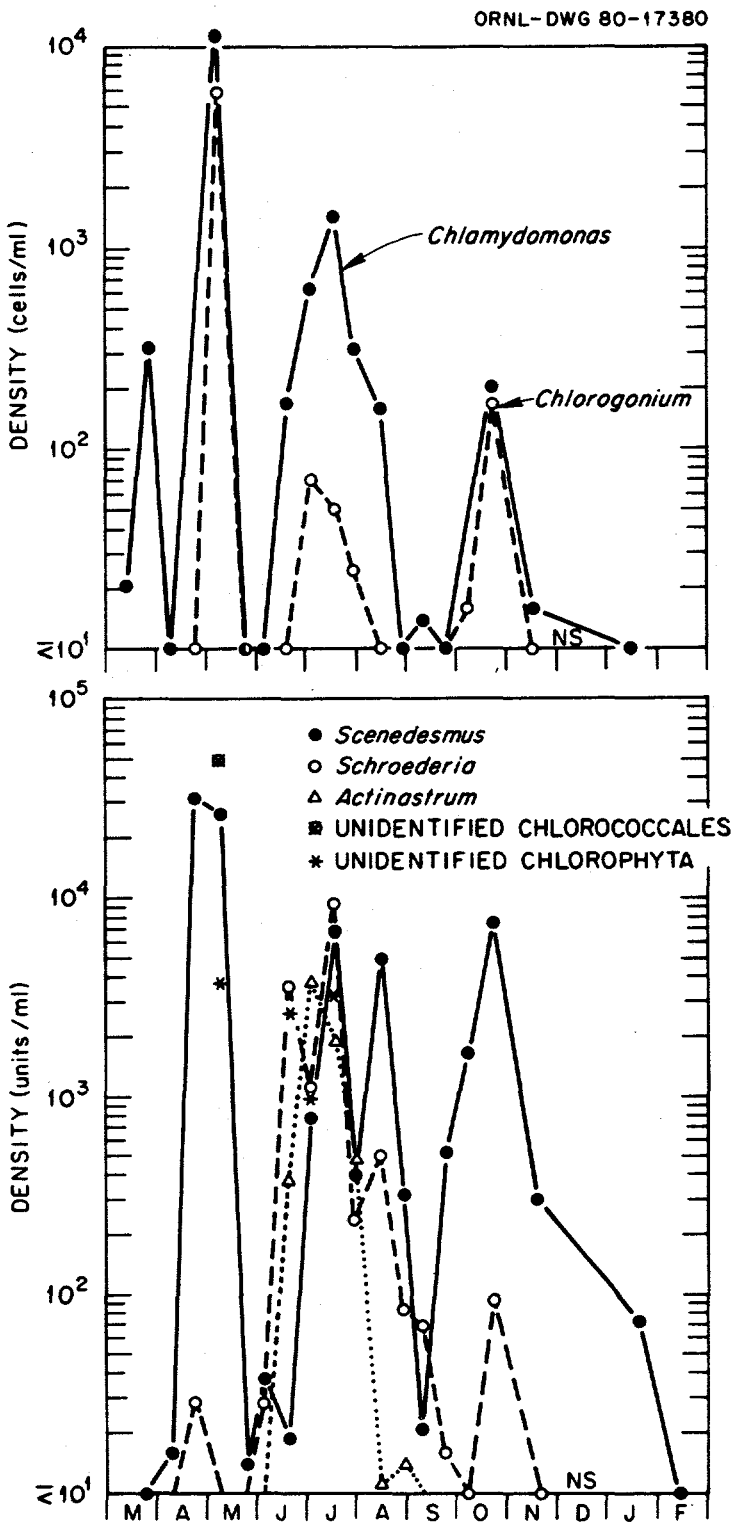

Fig. 4.10. Temporal fluctuations in the density (units/ml) of the most abundant Chlorophyta taxa at station White Oak Creek kilometer (WOCK) 1.1 in White Oak Lake, March 1979–February 1980. For colonial forms, 1 colony = 1 unit. NS = no samples.

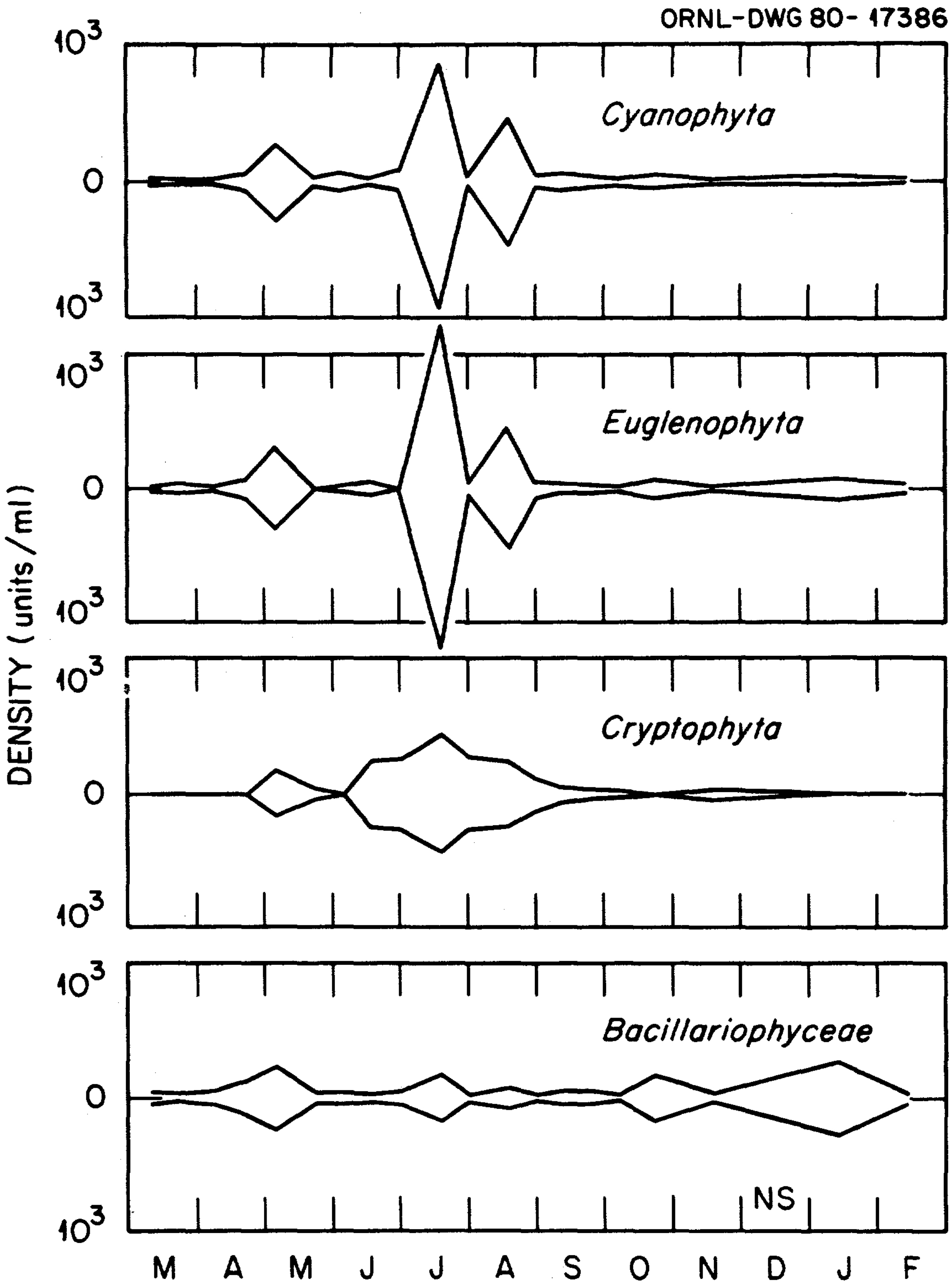

Fig. 4.11. Temporal distribution and abundance (units/ml) of the four major algal groups (Chlorophyta excluded) comprising the phytoplankton community at station White Oak Creek kilometer (WOCK) 1.1 in White Oak Lake, March 1979-February 1980. For colonial forms, 1 colony = 1 unit. NS = no samples.

Trachelomonas, which reached a density of 2303 cells/ml, but the smaller peak in August was primarily due to the presence of *Euglena* (837 cells/ml). Krumholz (1954b) also found peaks in the abundance of both of these genera at approximately the same time of year. A minor peak in the density of Euglenophyta occurred in the fall (late October) and consisted entirely of *Euglena* (122 cells/ml).

Cryptophytes and diatoms, two relatively minor components of the phytoplankton community in White Oak Lake, also exhibited distinct seasonal patterns in abundance (Fig. 4.11). The Cryptophyta were only abundant during the warmer months (May through August). Maximum densities of *Cryptomonas*, the only cryptomonad collected from the lake, occurred in mid-July (843 cells/ml). Diatoms, on the other hand, were more common during the cooler months, generally from late October through early May. The dominant genus throughout most of the year was *Navicula*, which reached a maximum density of 381 cells/ml in February. Although Lackey (1957) observed a large bloom of *Navicula* spp. (2336 cells/ml) in mid-August, densities in the present survey never exceeded 58 cells/ml over the same sampling period in the 1956 study (June through September).

A comparison of the composition and abundance of the phytoplankton community in White Oak Lake with the communities found at the other sampling sites is presented in Sect. 4.3.1.

Factors influencing abundance

Nutrients, primarily nitrogen and phosphorus, are important factors controlling phytoplankton population dynamics. Elevated levels of both nutrients occurred in White Oak Lake throughout the sampling period in 1979 (see Oakes et al., in press). Since the levels remained consistently high throughout the year, it is not likely that the dramatic declines in population density, especially the one following the major pulse in the spring (Fig. 4.9), were the result of nutrient limitation. Whether some other trace element became limiting at this time is unknown.

Some evidence exists to indicate that the populations are limited by the high flushing rate. The lake is extremely shallow, and the retention time is short (Sect. 2.1). Consequently, during periods of heavy rainfall, particulates (including phytoplankton) could be rapidly transported out of the lake. Large fluctuations in Secchi disc transparency were observed throughout the study, and the decline in abundance in late May coincided with a sharp drop in transparency (Fig. 2.3). In late May and early June the lake was extremely turbid; transparency on these sampling dates was 10 and 12 cm respectively. Moreover, dramatic declines in abundance occurred at approximately the same time in all the major groups. These results are consistent with the flushing rate hypothesis because all groups would be affected by the high flow rates. On the other hand, if nutrients were the limiting factor, all groups might not be influenced equally. That is, some species might be phosphorus limited, while others are nitrogen limited. As a result, seasonal shifts in the composition of the community would occur. The magnitude of the green algal pulses and their frequent occurrence throughout the entire growing season (April through October) suggests that nutrients are not limiting the phytoplankton populations in the lake.

4.2.2 Zooplankton

Previous studies

The zooplankton community in White Oak Lake has been described previously by Krumholz (1954b) and Bradshaw (1973, unpublished data). Since the sampling gear used in both studies was different from that used in the present survey (Sect. 3.1), comparisons of zooplankton abundance cannot be made. Quantitative sampling during the initial survey in 1950-53 was conducted using a 3-L Kemmerer water sampler, but avoidance of the gear by larger zooplankters (*Daphnia* and *Diaptomus*) produced inaccurate estimates of abundance (Krumholz 1954b). As a result, tow nets (No. 20 mesh or 76 μm) were employed after the first year. The nets, however, were unmetered, so the volume of water filtered was estimated. In the other study, a Juday trap fitted with a No. 10 mesh bucket was used to sample the zooplankton community from October 1972 to August 1973 (Bradshaw 1973, unpublished data). However, because of the large mesh size of the bucket (either 153 or 158 μm), the abundance of smaller forms, especially rotifers, may have been underestimated.

Although densities cannot be compared among the various surveys because of the variety (and, in some cases, inadequacy) of the sampling gear employed, identification of the most abundant species found within each of the three major groups (Rotifera, Cladocera, and Copepoda) would seem to be a reliable basis for comparison. Even though the frequency of sampling was different, the period of sampling included the summer months when maximum densities usually occur.

Results from the examination of the studies on the basis of dominant species were interesting. The most abundant rotifer in both studies was *Brachionus*. The genera *Moina* and *Daphnia* (in that order) were the most abundant cladocerans reported by Krumholz (1954b), but *Moina* was not found and *Daphnia* was relatively rare in the 1972-73 study. Instead, the dominant cladoceran was *Diaphanosoma brachyurum*, which belonged to a genus not found in the 1950-53 survey. The copepod community in the initial survey was dominated by *Diaptomus* (Copepoda: Calanoida), which was described as ". . . probably the most important single genus present on a yearly basis in the overall population of zooplankton" (Krumholz 1954b, p. 39). The community described in the later study was dominated by *Eucyclops agilis* (Copepoda: Cyclopoida), but no data were presented for *Diaptomus* (Bradshaw 1973, unpublished data). The genus *Euclops* was the most abundant cyclopoid collected in 1950-53. The dominant species found in the present survey are discussed below.

Taxonomic composition

The Rotifera were the dominant group of zooplankton in White Oak Lake during the 1979 survey. Forty-four of the 70 species (63%) and more than 80% of all the zooplankton collected from the lake were rotifers. The most abundant species belonged to genera that are primarily associated with littoral areas (Edmondson 1959). These included *Brachionus* spp. (nine species which together comprised 83% of the total number of rotifers collected), *Lecane* spp. (two species; 8%) and *Monostyla* spp. (three species; 4%). The most abundant planktonic (or limnetic, in the terminology of Pennak 1953) rotifer was *Keratella* spp. (5 species; 1%).

Crustacean zooplankton in the lake were mostly copepods, 66% of which were immature forms or nauplii (Fig. 4.12). Of the copepodids and adult copepods collected from the lake, nearly all (99%) belonged to the suborder Cyclopoida, and the most abundant species was *Eucyclops agilis*. The suborder Calanoida was represented by two species of the genus *Diaptomus* which were extremely rare (e.g., densities of *Diaptomus* spp. never exceeded 0.02 individuals/L). The most abundant Cladocera, the other major group of crustacean zooplankton, were *Moina micrura* and *Diaphanosoma leuchtenbergianum*, a species that "very probably...is merely a limnetic variety [of *D. brachyurum*]" (Edmondson 1959, p. 601).

Seasonal distribution and abundance

The zooplankton population in White Oak Lake exhibited several pulses between May and September and, as shown in Fig. 4.13, these pulses were primarily due to fluctuations in the abundance of rotifers. Although the most abundant genus (*Brachionus*) was represented by nine species, one of these, *Brachionus calyciflorus*, dominated the community. Fluctuations in the density of *B. calyciflorus* (Fig. 4.14) coincided with the fluctuations in total zooplankton abundance, and this species alone made up 66 and 95% of the spring and mid-summer pulses respectively. The small peak in rotifer abundance that occurred in the fall was due to an increase in the density of *Lecane* sp. (Fig. 4.14). Another littoral rotifer, *Monostyla* sp., was also abundant at this time (peak density of 6.0 organisms/L). Thus, the composition of the rotifer community had shifted from the *Brachionus*-dominated community observed during the spring and summer to one that was dominated by two littoral species in the fall.

Distinct pulses were also observed in the crustacean component of the zooplankton community in the lake (Fig. 4.15). The initial peak in both cladoceran and copepod abundance occurred in the spring (May) and was immediately followed by a second peak in June. Unlike the copepod pulses which consisted mostly of nauplii, the two cladoceran pulses were dominated by different species. In May, the most abundant species was *Diaphanosoma leuchtenbergianum* (7.2 individuals/L), but in June, *Moina micura* was dominant (14.1 individuals/L). These were the only times when the density of cladocerans in the lake exceeded that of the copepods.

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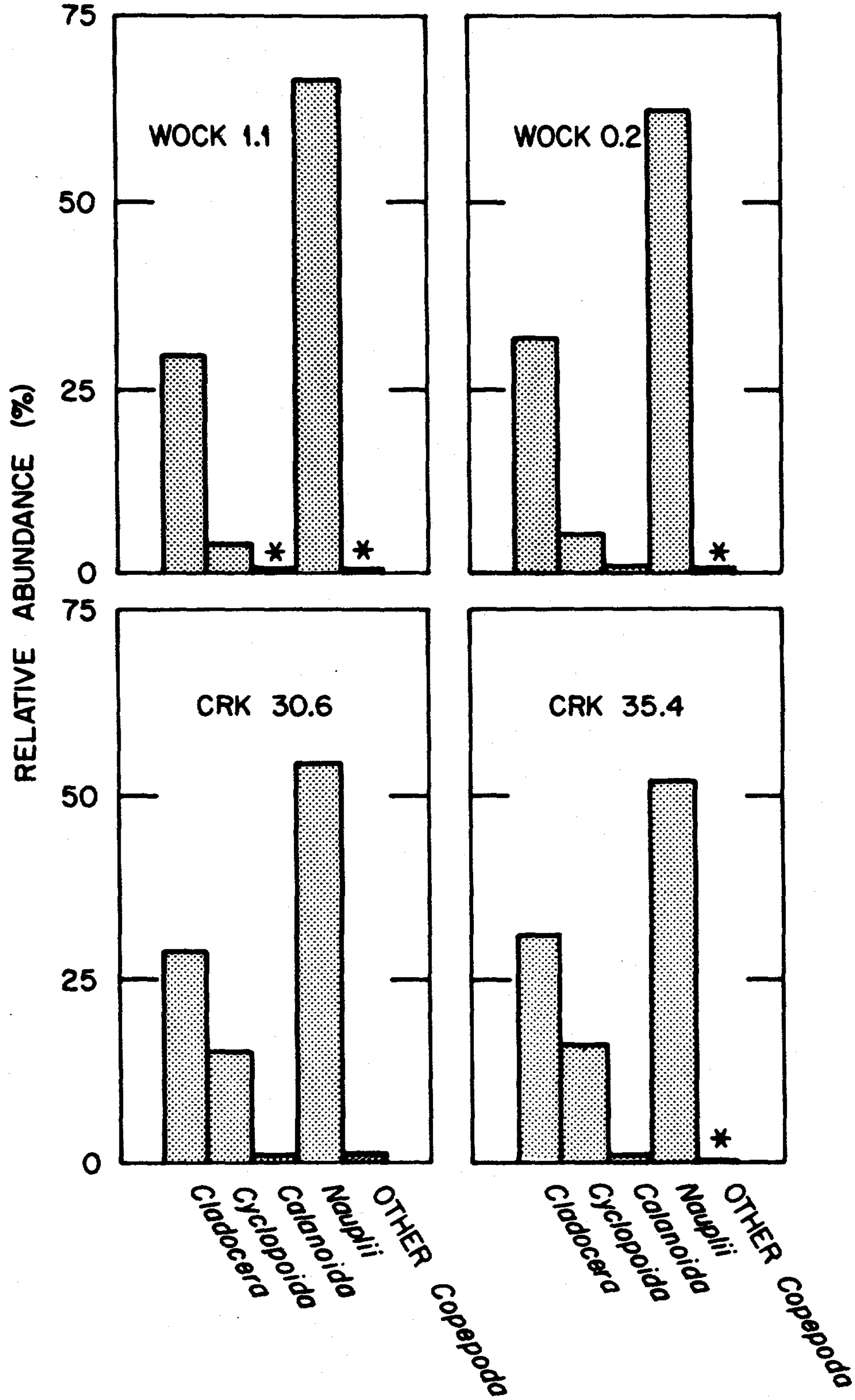

Fig. 4.12. Relative abundance (%) of crustacean zooplankton at stations White Oak Creek kilometer (WOCK) 1.1 (White Oak Lake), WOCK 0.2 (White Oak Creek embayment), and two sites in the Clinch River above [Clinch River kilometer (CRK) 35.4] and below (CRK 30.6) the mouth of White Oak Creek (CRK 33.5). Values were computed based on the total number of samples collected. * = <0.05%.

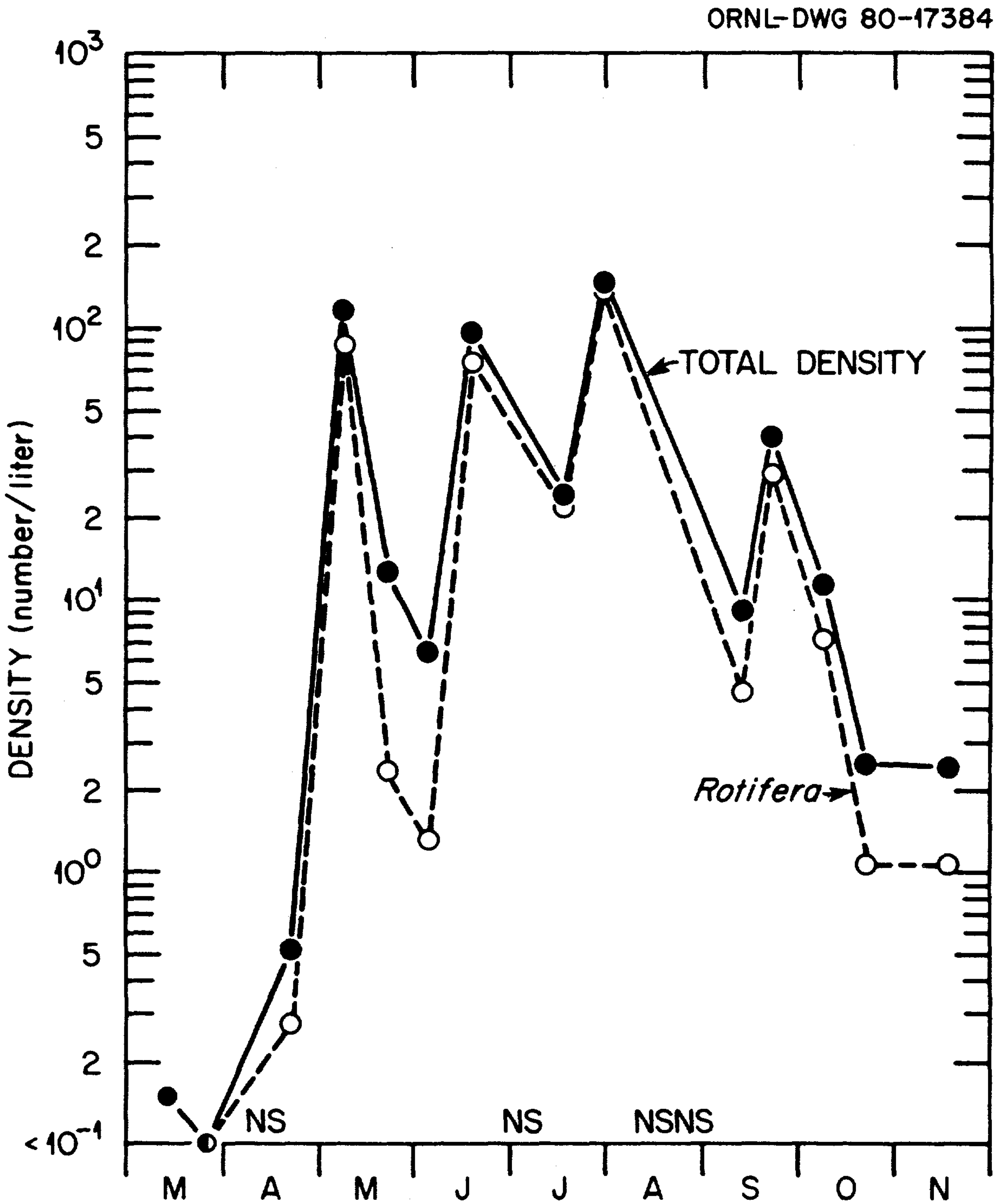

Fig. 4.13. Comparison of the temporal fluctuations in total zooplankton and rotifer densities (number per liter) at station White Oak Creek kilometer (WOCK) 1.1 in White Oak Lake, March 1979-November 1980. NS = no samples.

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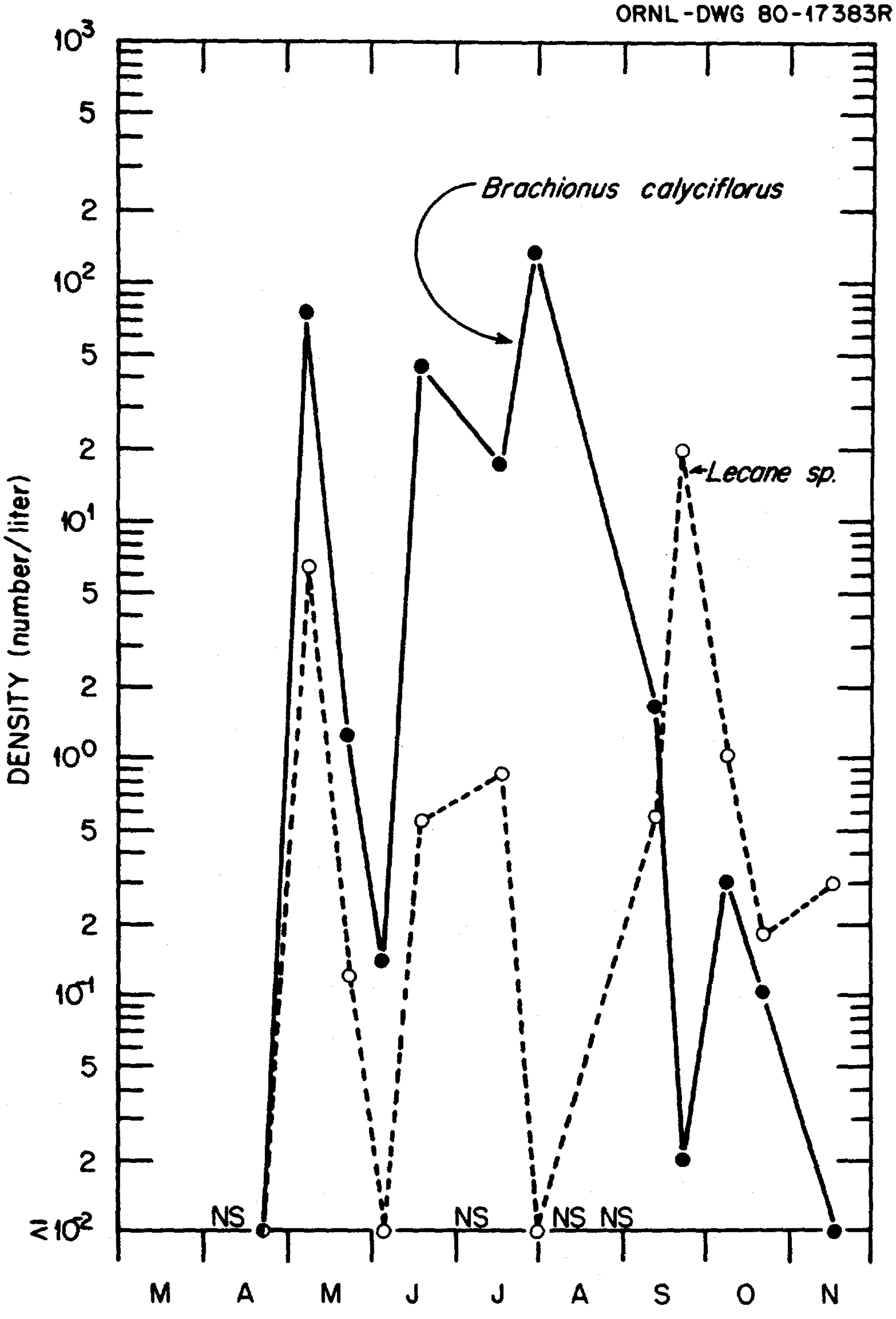

Fig. 4.14. Temporal fluctuations in the density (no./liter) of the two most abundant rotifers at station WOCK 1.1 in White Oak Lake, March 1979–November 1980. NS = no samples.

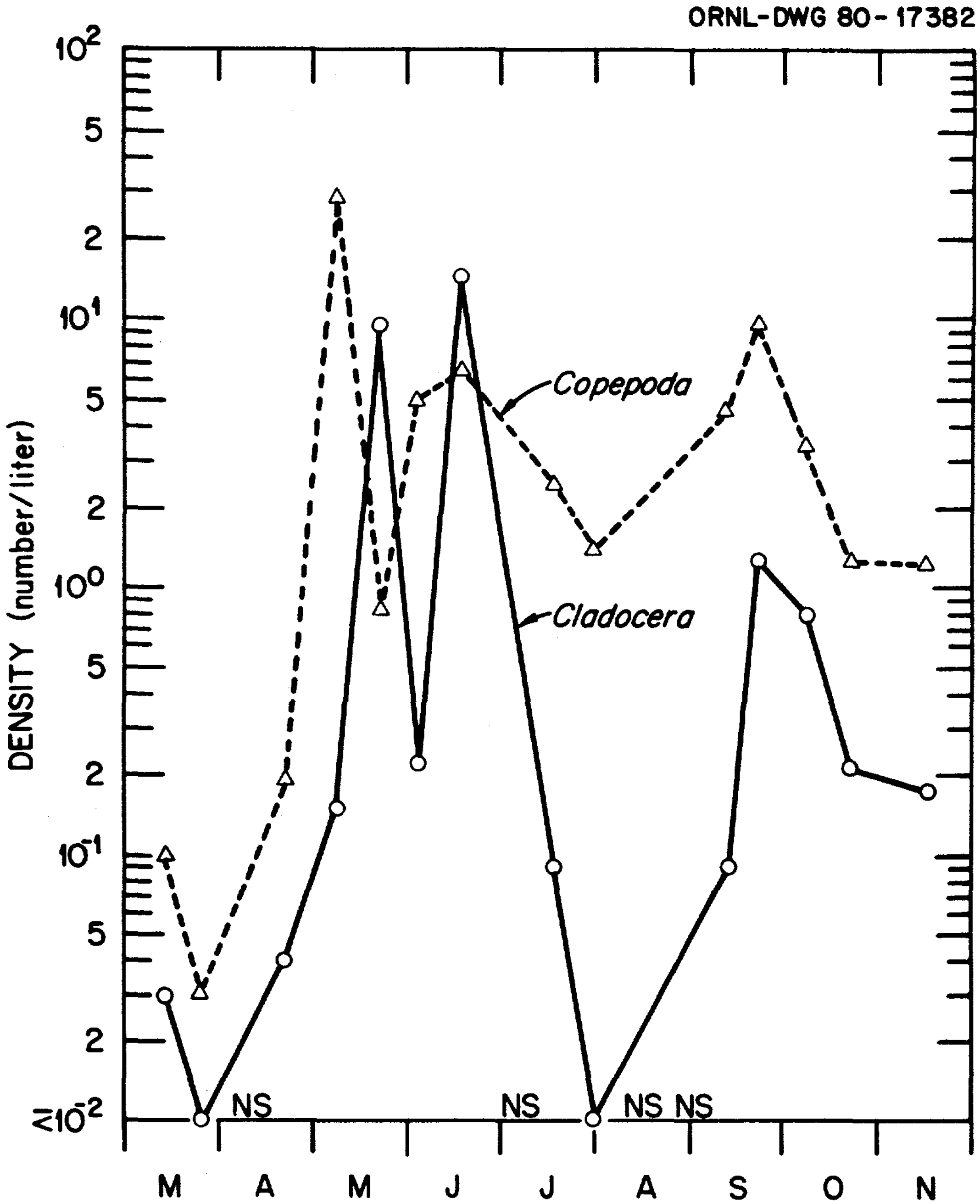

Fig. 4.15. Temporal fluctuations in the density (no./liter) of cladocerans and copepods at station WOCK 1.1 in White Oak Lake, March 1979–November 1980. NS = no samples.

Many factors could be associated with the occurrence of pulses in zooplankton abundance in White Oak Lake. For example, the spring and mid-summer pulses generally coincided with peaks in the abundance of food resources, namely small phytoplankton such as the unicellular flagellates, *Chlamydomonas*, *Chlorogonium*, and *Cryptomonas*. Thus, the decline in rotifer abundance in late May could be a response to the dramatic decrease in phytoplankton abundance that occurred at this time. However, zooplankton, especially the smaller planktonic rotifers, could also have been flushed from the lake with the phytoplankton. Although zooplankton, in general, would be less vulnerable than phytoplankton to being flushed from the lake, the vulnerability would vary among species, depending upon their size and motility, their habitat preference (i.e., limnetic species might have a higher probability of being transported out of the lake than littoral species), and the magnitude of the storm.

Although species interactions among rotifers are poorly understood, the predation of *Asplanchna* on *Brachionus* is an exception (Wetzel 1975). In White Oak Lake, however, predatory rotifer populations were extremely small. Densities of genera such as *Asplanchna*, *Synchaeta*, and *Ploesoma*, which are all planktonic predators, never exceeded two individuals per liter, and during the period when *Brachionus calyciflorus* densities reached 135/L, *Synchaeta* densities were only 0.3/L (the other genera were not found). This genus was the most common rotifer found at the other sampling sites (Sect. 4.3.2).

A comparison of the composition and abundance of the zooplankton community in White Oak Lake with the communities found at the other sampling sites is presented in Sect. 4.3.2.

4.2.3 Ichthyoplankton

Two ichthyoplankton taxa were collected in the plankton tows in White Oak Lake: Clupeidae and *Lepomis*. Clupeids first appeared in the samples on May 8 and were found in most of the weekly samples through July 31 (Fig. 4.16). The highest mean density of Clupeidae larvae was $12.1/m^3$ in the June 12 samples. With the exception of one 8-mm TL and four 7-mm TL fish, all larvae ranged in length from 4 to 6 mm.

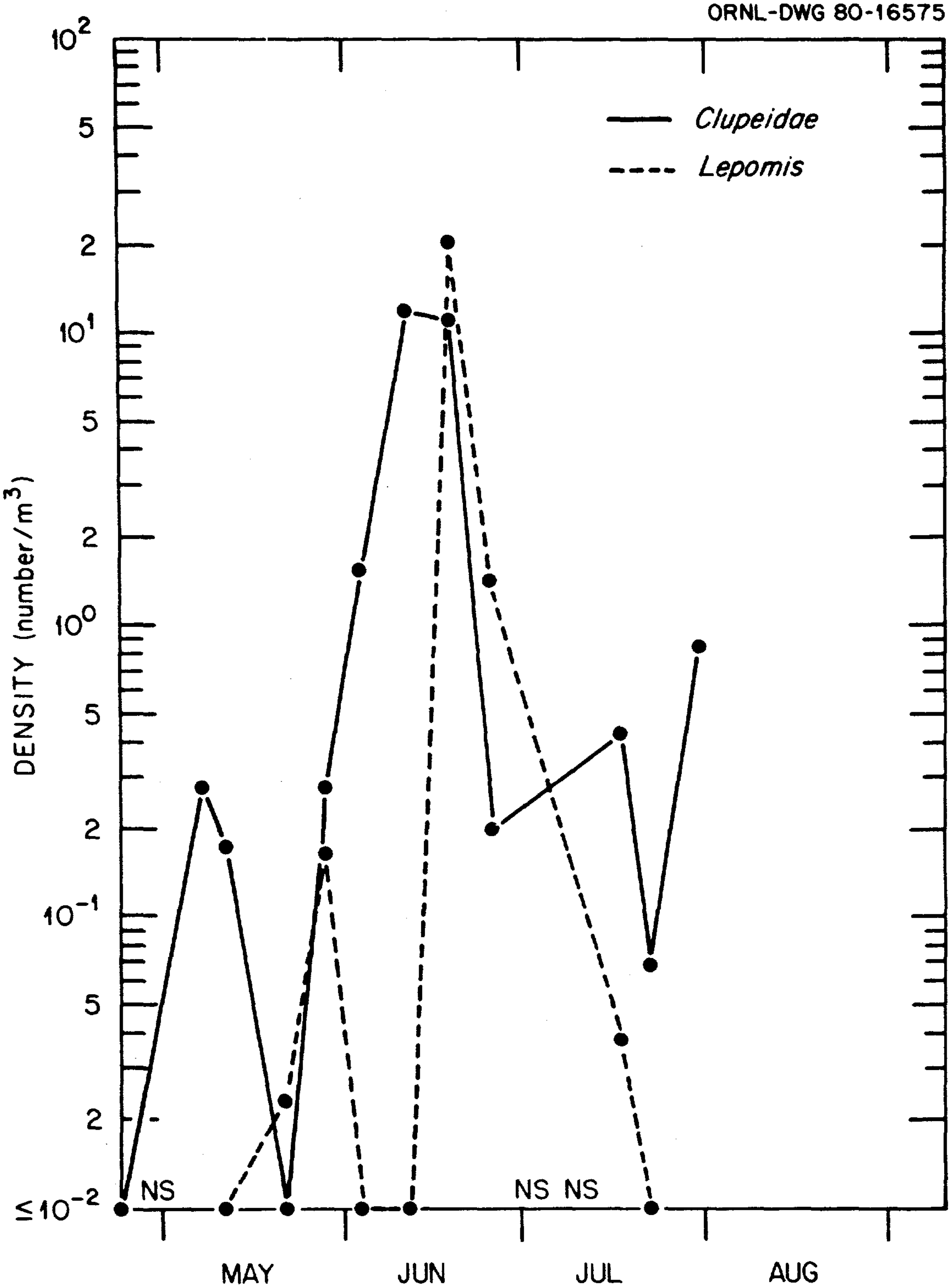

Fig. 4.16. Seasonal density patterns (arithmetic means of two replicates) of Clupeidae and *Lepomis* larvae in White Oak Lake [station White Oak Creek kilometer (WOCK) 1.1], 1979. NS = no samples taken.

Lepomis larvae were collected in White Oak Lake on May 24 and 29 and again between June 19 and July 18 (Fig. 4.16). A peak density of 20.8 larvae/m^3 was recorded on June 19. The majority of *Lepomis* larvae were 5 or 6 mm in total length, and none were greater than 8 mm TL.

Adult clupeids were not found in White Oak Lake during this survey (Sect. 4.2.6), but based on previous adult fish studies, it is likely that the larval clupeids in the ichthyoplankton samples were gizzard shad (*Dorosoma cepedianum*). There is no record of threadfin shad (*D. petenense*) from the lake. *Lepomis* larvae were probably either bluegill, redear sunfish, or bluegill/redear hybrids. Larval forms of other adult fish collected in White Oak Lake (i.e., largemouth bass and *Gambusia*) were not found in the ichthyoplankton samples. Although *Gambusia* are abundant in the lake, they occur primarily in shallow nearshore areas in the western and upper end of the lake where tow samples could not be taken.

The presence of relatively high densities of small *Lepomis* and Clupeidae larvae in the ichthyoplankton samples indicates that spawning of these taxa does occur in White Oak Lake. In fact, peak densities of clupeid larvae were an order of magnitude greater than peak densities at the other sampling stations in this survey. The absence of larvae longer than 8 mm is probably related to the reduced towing velocities that were necessary in the lake (Sect. 3.1) and increased gear avoidance capabilities of larger larvae, since numerous juvenile sunfish were collected by electroshocking (Sect. 4.2.6).

4.2.4 Periphyton

Previous studies

The periphyton community in White Oak Lake was investigated by Neal, Patten, and DePoe (1967), who described the successional pattern during colonization. Principal genera during the early stages of succession were the blue-green algae *Microcystis* and *Oscillatoria*. Diatoms, especially *Navicula*, *Cymbella*, and *Fragilaria*, were important but were less abundant than the blue-greens and were never dominant during the study. After five weeks, the green alga *Oedogonium* appeared and was followed by other filamentous greens, such as *Spirogyra*, *Chaetophora*, and *Stigeoclonium*.

The rapid growth of periphyton in the lake was attributed to (1) enrichment by chemical and treated sanitary wastes from ORNL and (2) high water temperatures during the summer.

Taxonomic composition

The major groups of algae comprising the periphyton community in White Oak Lake were diatoms (63% of the total numbers), greens (32%), and blue-greens (3%). Unlike the communities found at the other sampling sites where a single taxon (*Achnanthes*) was numerically dominant, several genera were relatively abundant in White Oak Lake. Important diatoms included *Navicula* (30% of the total diatoms), *Achnanthes* (29%), and *Cymbella* (19%). The most abundant green algae were Stigeoclonium (41% of the total Chlorophyta) and *Ankistrodesmus* (37%). The dominant blue-green alga was *Oscillatoria* (81%).

Seasonal abundance patterns

Both diatom and green algal abundance exhibited similar fluctuations during the sampling period (Fig. 4.17). Diatoms, however, reached a maximum density during the winter, whereas the peak in Chlorophyta abundance occurred during the summer. Both groups exhibited seasonal shifts in the abundance of particular genera. For example, *Cymbella* and *Achnanthes* were abundant during July and August but were replaced as the dominant genera by *Navicula* in late summer. In January, the community was dominated by all three genera. Similarly, the peak in Chlorophyta density in August was primarily composed of *Ankistrodesmus* (7918 cells/cm^2) which declined in density throughout the remainder of the study. From July through September, densities of *Stigeoclonium* remained near 4000 filaments/cm^2. Dominant genera in January included *Surirella* (3056 units/cm^2), *Synedra* (2374 units/cm^2), and *Gloeocystis* (2314 colonies/cm^2). The density of *Ankistrodesmus* and *Stigeoclonium* at this time was less than 120 units/cm^2.

The peaks observed in abundance, as determined from direct counts, coincided with peaks in both biomass and chlorophyll a from July through March (Fig. 4.18). Maximum biomass and chlorophyll a occurred during

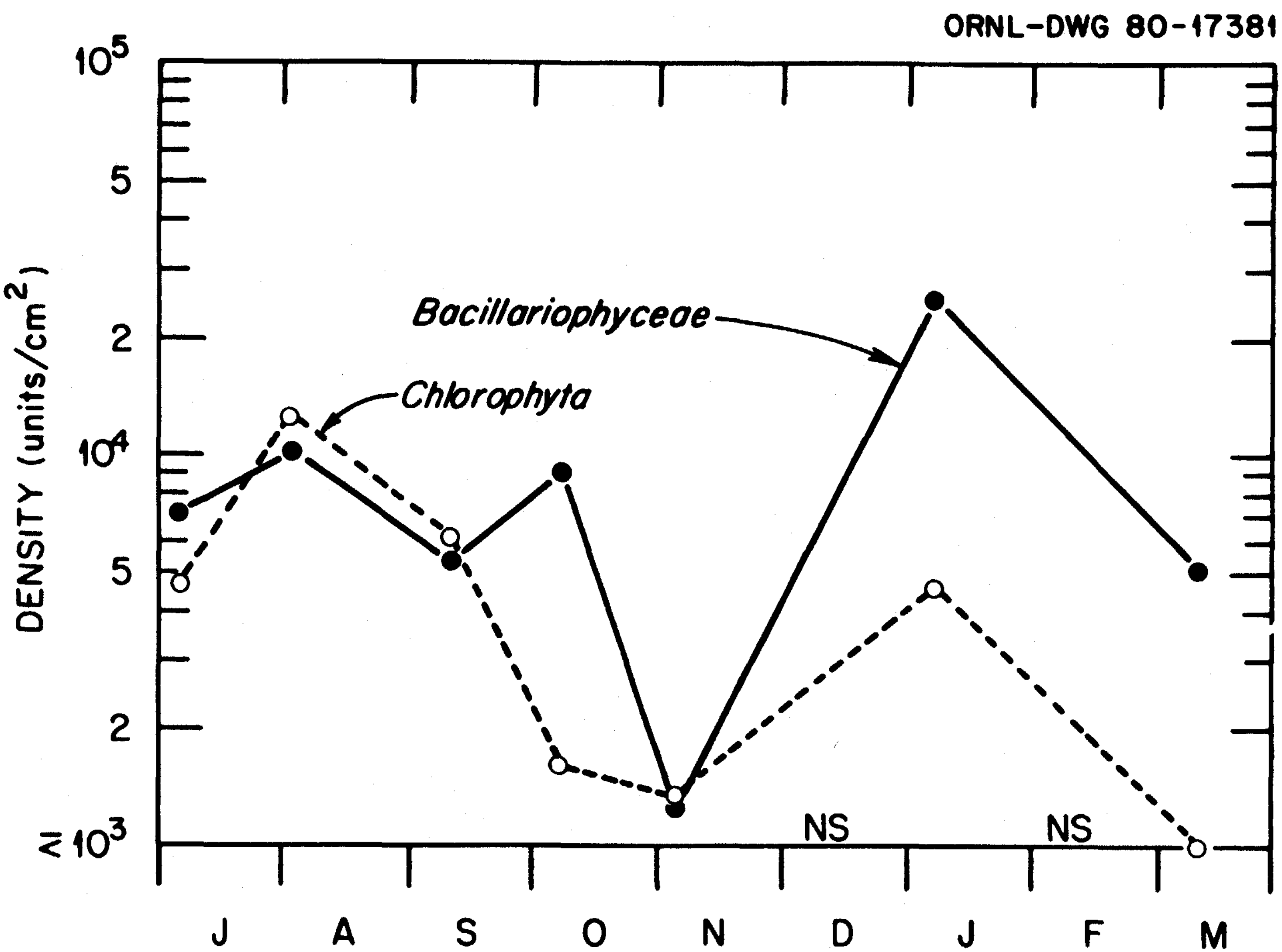

Fig. 4.17. Temporal fluctuations in the density of Bacillariophyceae (diatoms) and Chlorophyta (units/cm^2) on plexiglass slides at station White Oak Creek kilometer (WOCK) 1.1 in White Oak Lake, July 1979–March 1980. Dates shown on the graph represent the last day of the 28-d colonization period. For colonial forms, 1 colony = 1 unit. NS = no samples.

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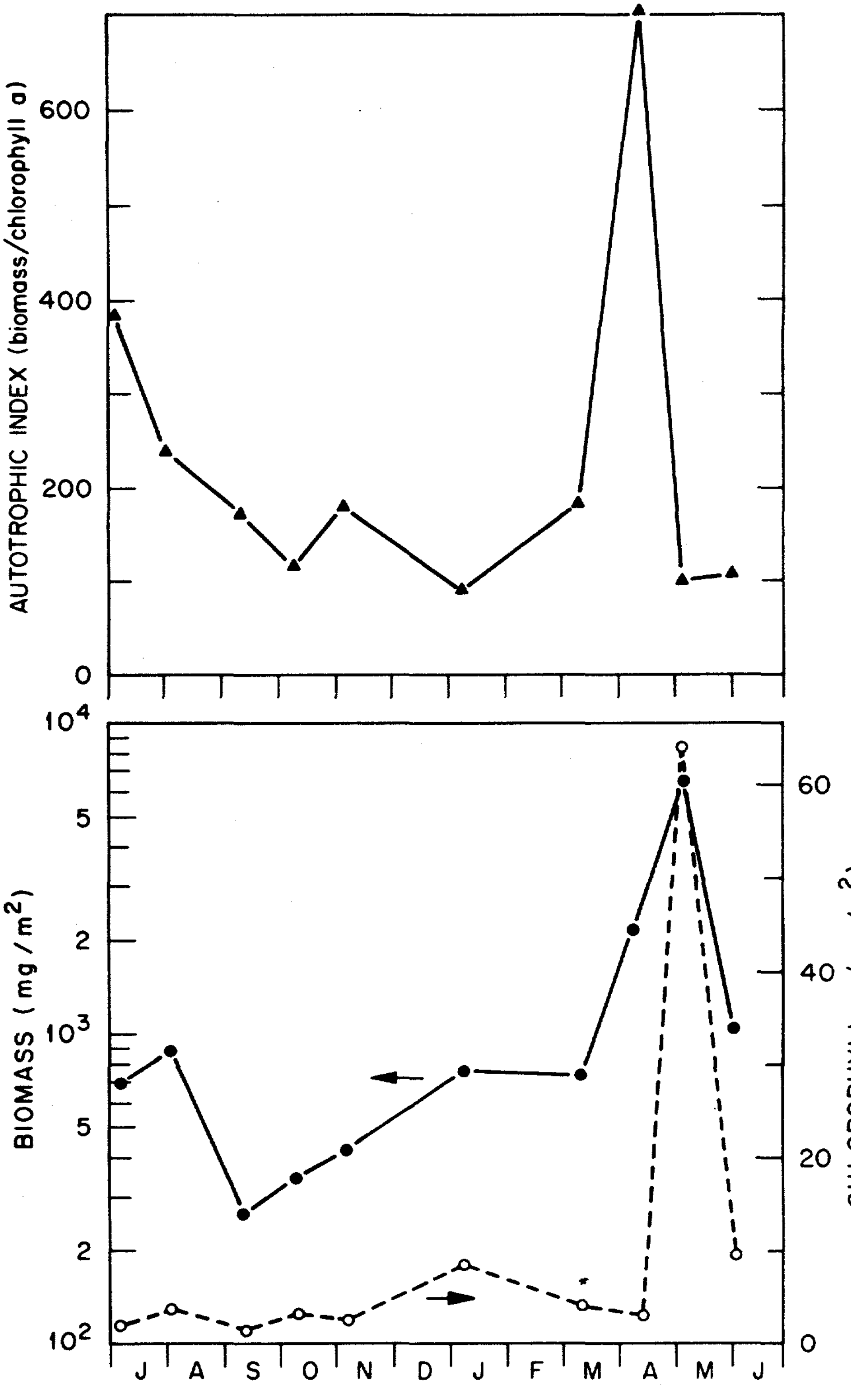

Fig. 4.18. Temporal fluctuations in biomass (mg/m^2), chlorophyll a (mg/m^2), and ratio of biomass: chlorophyll a (autotrophic index) of periphyton on plexiglass slides at station White Oak Creek kilometer (WOCK) 1.1 in White Oak Lake, July 1979-June 1980. Dates shown on the graph represent the last day of the 28-d colonization period. NS = no samples.

the spring. Most of the periphyton community at this time consisted of autotrophs, as indicated by the low AI values. The dramatic increase in both periphyton biomass and chlorophyll a during the spring is not surprising; a similar increase in phytoplankton abundance occurred at approximately the same time in 1979.

4.2.5 Benthic macroinvertebrates

Previous studies

Extensive sampling (primarily qualitative) of the benthic macroinvertebrate fauna in White Oak Lake was initially conducted by Krumholz (1954b). Samples taken from the littoral zone throughout the lake over a three-year period (1951-53) resulted in the collection of 64 taxa (Krumholz 1965b, Table 67). Although quantitative sampling was also conducted at nine sites, the frequency was limited (one to four sampling dates per station), and only eight taxa were identified. Similarly, a total of seven taxa were collected from limited sampling near White Oak Dam in 1974-75 (Table 4.9). In neither of these earlier surveys was sampling conducted during the summer (June-September). Sampling near WOCK 1.1 between April and October 1979 resulted in the collection of 14 taxa (Appendix A-5).

Because of the limited quantitative sampling in the two earlier surveys, comparisons of these results with those obtained in 1979 are difficult. It is apparent, however, that the *Chaoborus* populations in the lake have declined since the initial survey was conducted in 1951-53. Densities reported during this survey exceeded 100 individuals/0.1 m^2 (Table 4.9), and *Chaoborus* made up about 65% of the diet (on a volume basis) of black croppie between April and September (Krumholz 1954c, Table 25). Only three individuals (or 3.2 individuals/0.1 m^2), however, were found in the 12 samples taken in 1974-75, and a single individual was collected in 1979. Krumholz (1954b) reported that *Chaoborus* appeared to be almost entirely a deep-water (>1 m) species. Since both the 1974-75 and 1974 sampling sites were located in the lower (and deepest) region of the lake near the dam, the high *Chaoborus* densities in 1952 and 1953 are not the result of biased sampling in habitats that

Table 4.9. Mean densities (number of individuals per 0.1 m^2) of benthic macroinvertebrates reported from previous surveys conducted in lower White Oak Lake in the vicinity of station White Oak Creek kilometer (WOCK) 1.1

Taxon	1950-53[a]				1974-75[b]		
	Apr. 1952		Feb. 1953		Oct. 1974	Nov. 1974	Feb. 1975
	Site 15	Site 41	Site 15	Site 41			
Coleoptera	1.5						
Diptera							
Ceratopogonidae					2.2	4.3	
Chironomidae[c]	60.7	85.9	48.9	85.9	52.7	65.7	64.6
Chaoborus sp.	114.1	151.1	277.0	186.7		3.2	
Ephemeroptera							
Hexagenia sp.					1.1		
Oligochaeta							
Lumbriculidae					7.5		
Naididae					2.2		5.4
Tubificidae	10.4[d]				2.2	6.5	22.6

[a]Source: Krumholz (1954b), Tables 69, 71. Densities based on three Ekman dredge (15 × 15 cm) hauls at each site. Samples were sieved through a standard No. 70 mesh screen. Sites 15 and 41 were located 615 and 330 m, respectively, above White Oak Dam.

[b]Source: B. G. Blaylock, unpublished data. Densities were computed from data reported as the total number of individuals in four Ponar dredge (15 × 15 cm) hauls. Sampling site was located 75 m above White Oak Dam.

[c]Reported as Tendipedidae by Krumholz (1954b).

[d]Reported as *Tubifex* sp.

were not encountered in the latter surveys. Instead, the data suggest that the low densities found 20-25 years after the initial survey are indicative of a real decline in the abundance of *Chaoborus* in the lake. Adequate information is not available, however, to evaluate the possible cause(s) for this reduction in population density.

Taxonomic composition

Taxa belonging to three phyla were collected from White Oak Lake between April and October 1979 (Appendix A-5). Representatives of the phylum Arthropoda (class Insecta) composed 79% of all the organisms collected from the lake. The relative abundance of the other phyla, Mollusca and Annelida, was 14% and 7% respectively.

The composition of the benthic community exhibited a pronounced seasonality. Representatives of the order Diptera (Arthropoda: Insecta) were numerically dominant in April and June, composing more than 90% of the individuals in these samples. The two most abundant groups at this time were the Chironomidae and Ceratopogonidae (all identified as *Palpomyia*). From July through October, a gradual shift in composition occurred as other taxa became abundant. During this period, for example, the relative abundance of Ephemeroptera (mayflies) and Odonata (damselflies, and dragonflies) ranged from 20 to 36% and from 3 to 10% respectively. Neither order was represented in the samples collected in April and June. Similarly, the relative abundance of *Physa* (Mollusca: Gastropoda) gradually increased from July (13%) to October (48%). The only mussel collected from the lake was *Corbicula manilensis* (Mollusca: Pelecypoda); a single individual was found in a sample taken from the old creek channel near the east shore in September. Oligochaetes (Annelida: Oligochaeta) were a minor component of the benthic community. Although present during all sampling dates, the relative abundance ranged from 3% (April) to 10% (September).

Temporal patterns in density

The abundance of benthic macroinvertebrates in White Oak Lake varied between April and October, with peak densities occurring in early June and late August. The increase in density between April and June was due to a tenfold increase in the abundance of chironomids (Fig. 4.19). Since the chironomid population (number of species unknown) in White Oak Lake usually emerges very early in the spring, the sharp increase in June could represent the appearance of the second generation of the year, which is probably the largest (B. G. Blaylock, personal communication). The low numbers in April suggest that the peak emergence period occurred prior to the first sampling date (April 18) and that most of the population at this time may have consisted of small individuals that were not retained by the screens used to sieve the samples (Sect. 3.1). The occurrence of several chironomid pupae in the June samples also suggests that the decline observed in July was due to emergence. Larvae identified from the June samples were *Clinotanypus* sp., *Parachironomus* spp., *Polypedilum halterale*, and *Procladius* sp. Numerous pupae were also observed in the August samples, indicating another emergence (either of the same or different species) was occurring.

The second maxima in August was primarily due to an increase in the density of *Physa* and two genera of Ephemeroptera (mayflies), *Caenis* and *Callibaetis*, both of which are common inhabitants of small ponds and the backwaters of streams (Pennak 1953; Traver 1932). Their emergence in late summer (as evidenced by the presence of individuals with well-developed wing pads) probably accounts for the low densities observed in October. Since growth is limited by the low water temperatures during the winter (Fig. 2.4), the nymphs were still too small in the spring to be retained by the screen. The relatively high densities of the snail *Physa*, probably *P. crocata* (B. G. Blaylock, unpublished data), from August through October is due to reproduction and growth during the summer. Individuals were found in all 15 samples taken during this three-month period. Higher densities of dragonfly (two genera) and damselfly (two genera) nymphs were also observed during late summer and fall, but their abundance was low. The most common genus was the dragonfly *Perithemis*, which reached a mean density of 7.8 individuals/0.1 m^2 in late August. Densities of the other genera were generally less than 1.7 individuals/0.1 m^2 between July and October.

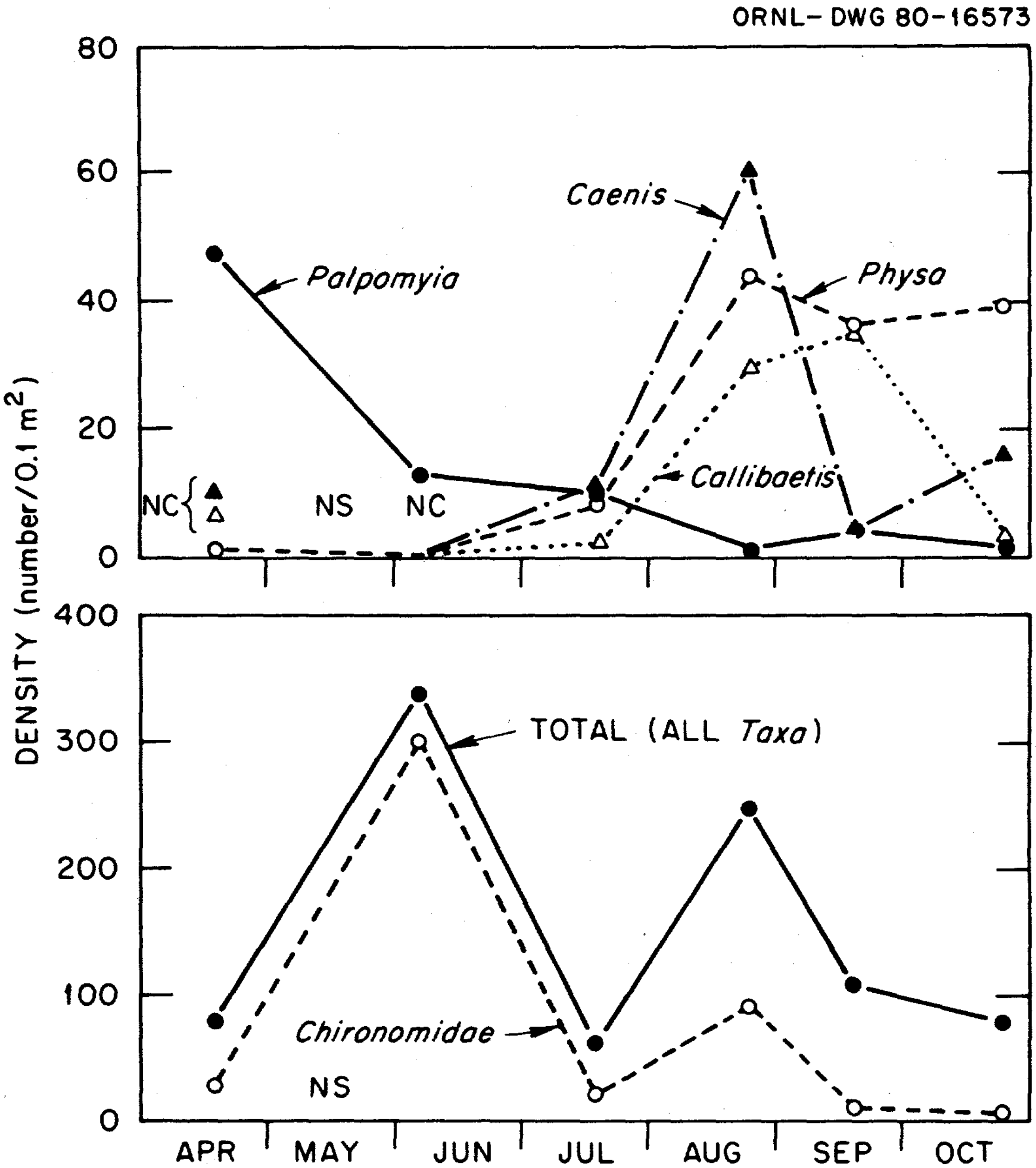

Fig. 4.19. Comparison of the fluctuation in total benthic macroinvertebrate density (all taxa combined) with changes in the density of the five most abundant taxa in White Oak Lake, April-October 1979. NC = no individuals collected; NS = no samples taken.

4.2.6 Fishes

Previous studies

The only extensive survey of the fish populations in White Oak Lake was conducted in 1950-53 (Krumholz 1954c) using mark-recapture techniques, and rotenone changes in population size were examined over a three-year period. Age and growth studies and an analysis of food habits were also conducted. Although more recent studies of the fish populations in the lake (Kolehmainen 1969; Auerbach et al. 1974) focused on radiological effects, some information was obtained on species composition. Since the initial survey in 1951-53, however, no data similar to that collected in the present survey (i.e., seasonal changes in species abundance) have been collected.

Species composition and abundance

The composition of the fish community in White Oak Lake has changed considerably since the first survey was conducted in 1950-53 (Table 4.10). Although the bluegill is still the most abundant species in the lake, several species that were abundant in the initial study (e.g., black crappie and yellow bullhead populations in the lake were estimated to be about 5300 and 1100 individuals, respectively, in 1953) have not been collected in subsequent sampling of the lake. That changes in composition can occur over relatively short periods of time was indicated by the decline in population size, between the fall of 1950 and the spring of 1953, of white crappie (1140 to 6) and golden redhorse (375 to 28) (Krumholz 1954c, Table 8). Neither species has been recorded from the lake since 1953.

With the possible exception of the goldfish (relative abundance of 1.5% in 1973), the composition of the community in 1979 was similar to that observed in 1973. Although several of the species found in 1973 were not collected in 1979, most were represented by only a single individual (from a total of 4676 fish collected) in the 1973 collection. These species may have been present in the lake during the present survey, but they were not collected because of either their low abundance in the sampling area or the limited sampling that could be done.

Table 4.10. Composition of the fish community in White Oak Lake as determined from extensive sampling of the lake on four occasions

Species	1950–53	1967–68	1973	1979
Catostomidae				
Catostomus commersoni (White sucker)	x			
Moxostoma erythrurum (Golden redhorse)	x			
Centrarchidae				
Lepomis gulosus (Warmouth)		x		
Lepomis macrochirus (Bluegill)	x	x	x[a,b]	x
Lepomis microlophus (Redear sunfish)		x		x(?)[c]
Micropterus salmoides (Largemouth bass)	x	x	x[b]	x
Pomoxis annularis (White crappie)	x			
Pomoxis nigromaculatus (Black crappie)	x			
Clupeidae				
Dorosoma cepedianum (Gizzard shad)	x	x	x[b]	x[d]
Cyprinidae				
Carassius auratus (Goldfish)	x	x	x[b]	x[e]
Cyprinus carpio (Carp)	x		x[f]	x[e]
C. auratus × *C. carpio* (Hybrid)	x			
Notemigonus crysoleucas (Golden shiner)		x	x[f]	
Notropis (Shiners)			x[b]	
Pimephales promelas (Fathead minnow)			x[f]	
Ictaluridae				
Ictalurus melas (Black bullhead)			x[f]	
Ictalurus natalis (Yellow bullhead)	x			
Ictalurus nebulosus (Brown bullhead)			x[f]	

Table 4.10 (continued)

Species	1950-53	1967-68	1973	1979
Poeciliidae *Gambusia affinis* (Mosquitofish)	x	x	x[b]	x

Sources: 1950-53 data (Krumholz 1954c); 1967-68 (Kolehmainen and Nelson 1969); 1973 (Auerbach et al. 1974, Table 5.5).

[a]Unidentified *Lepomis* hybrids also reported.

[b]Also collected from White Oak Lake on various occasions between 1975 and 1978 (B. G. Blaylock, unpublished data).

[c]Identity uncertain; may be hybrid (*L. microlophus* × *L. macrochirus*).

[d]Larval clupeids (probably gizzard shad) were common in ichthyoplankton samples (see Sect. 4.2.3).

[e]Observed in the lake (B. G. Blaylock, personal communication).

[f]Relative abundance was 0.02% (1 individual from a total of 4676 fish).

The most abundant species in the lake during the present survey (as well as those conducted in 1950-53 and 1973) was the bluegill, composing 78% of the fish collected between March and September (Table 4.11). The peak abundance of *Lepomis* sp. larvae occurred in mid-June, suggesting that spawning activity was greatest in early June (Sect. 4.2.6). An increase in small (probably young-of-the-year) bluegill was observed in the electroshocking sample taken on July 26, 1979 (Fig. 4.20). Several small fish identified as *Lepomis* sp. (mean total length = 22.5 cm; range = 20.0 to 26.0; n = 9) were also collected in the sample. Their occurrence coincided with the decline of *Lepomis* sp. larvae after mid-July, probably as a result of increased gear avoidance capability. Other, less abundant species were also found in the lake during 1979 (Table 4.11).

The abundance of mosquitofish was probably greatly underestimated by sampling along the southeast shore of the lake. Numerous schools were observed directly across the lake near the boat ramp, and large numbers were collected at station WOCK 2.1 just above the lake (Sect. 4.1.4). Previous sampling has indicated that mosquitofish are especially abundant in the very shallow northeastern end of White Oak Lake near the area where the creek enters the lake (Auerbach et al. 1974; B. G. Blaylock, personal communication). In a 1973 survey, for example, this species made up 43% of the total fish (4676) collected from this region of the lake (Auerbach et al. 1974, Table 5.5). However, because of the selectivity of the gear used (small minnow seines) and the restriction of sampling efforts to the upper end of the lake, the actual relative abundance of mosquitofish in the lake may be somewhat lower. Hybrids (possibly redear x bluegill) made up 3% of the fish collected in 1979 and were also observed in 1973 (relative abundance not reported). Although no adult gizzard shad were collected in the present survey, the high abundance of clupeid larvae in the lake suggests that a self-sustaining population may inhabit the lake. Largemouth bass abundance in the lake was relatively low (3% of the fish collected) in 1979. Electrofishing was conducted in an area (east shore of the lake near the dam) where most of the bass were collected in the past (B. G. Blaylock, unpublished data). Their low abundance was confirmed when numerous

Table 4.11. Number of fish collected in White Oak Lake by gillnetting (G) and electroshocking (E) from March through October 1979

NC = no fish collected; NS = no samples taken

Species	Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Total
	G	E	G	E	G	E	G	E	G	E	G	E	G	E[a]	G	E	
Bluegill					1		1	29		38		22		7			98
Redear × Bluegill (?)								2		1				1			4
Lepomis sp.										9		4		4			17
Largemouth bass										3							3
Mosquitofish										3							3
	NC	NS	NC	NS		NS			NS		NS[b]		NS[b]		NS[b]	NS[c]	

[a]Large amounts of vegetation in lake made it difficult to locate stunned fish.

[b]Gill net could not be set due to vegetation (primarily filamentous algae) on lake.

[c]No samples were taken due to large amounts of pondweed and high conductivity.

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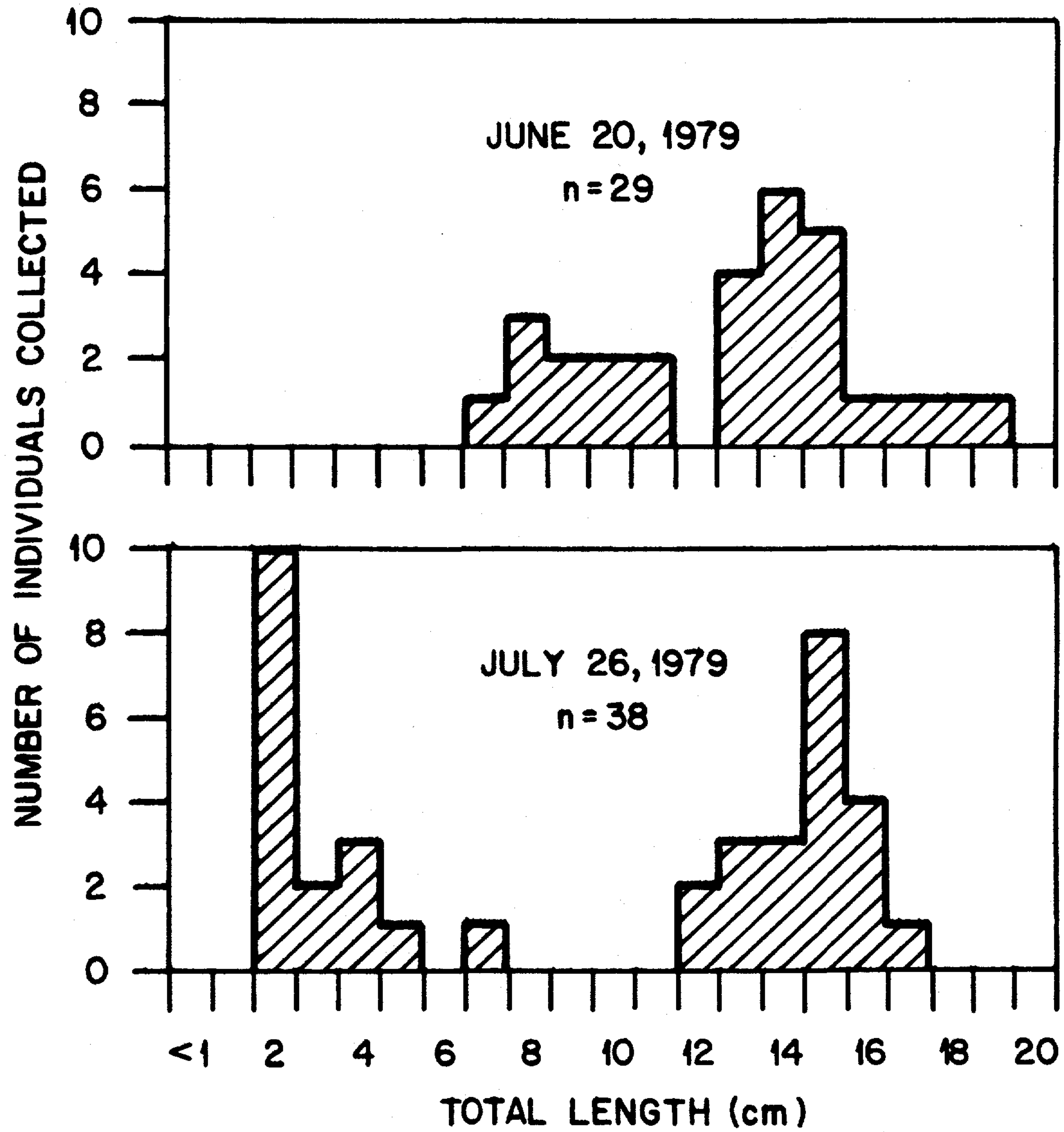

Fig. 4.20. Length-frequency histograms for bluegill collected by electroshocking in White Oak Lake.

areas of lower White Oak Lake were electroshocked on June 20, 1979, in order to collect specimens for tissue analysis. A total of three fish was collected.

The effect on the fish populations when the lake level was dropped in late November 1979 is unknown, since sampling had to be terminated at that time (Sect. 3.1). Some individuals may have been carried over the dam, a phenomenon that has been observed during high flow periods (T. W. Oakes, personal communication). On the other hand, changes in composition (or abundance) may have occurred as a result of the movement of fish from below the dam into White Oak Lake. Such an exchange occurred in early 1980 during the construction of a berm just below the dam (B. G. Blaylock, personal communication).

4.3 CLINCH RIVER AND WHITE OAK CREEK EMBAYMENT

4.3.1 Phytoplankton

Previous studies

The phytoplankton community in White Oak Creek embayment was sampled by Lackey (1957) during the summer of 1956. He reported "a great development" of plankton in this area (Table 4.12), which was warmer than the river, quiescent, and seeded by water from White Oak Lake. Seven years later, Melton Hill Dam was completed and the hydrology of the embayment was significantly altered (see Sect. 2.1). The area is no longer quiescent and the differential in water temperature between the embayment and the river is probably less than it was prior to operation of Melton Hill Dam.

The data presented in Table 4.12 were compared with the results obtained during the same period in 1979 (four sampling dates: July 18 and 31; August 14 and 29). Of the blooms reported by Lackey (1957), the only genus with a density greater than 500 cells/ml in 1979 was *Gonium* (44 colonies/ml × 16 cells/colony = 704 cells/ml on August 31). However, the densities of *Actinastrum* and *Scenedesmus* (after converting from colonies/milliliter to cells/milliliter from data on the actual number of cells in ten colonies) exceeded 500 cells/ml on August 31 (7950 and 8440 cells/milliliter). While some changes could have occurred in the

Table 4.12. Typical blooms (≥500 cells/ml) observed during the summer of 1956 in White Oak Creek embayment

	Density (cells/ml)
July 26	
Cryptomonas erosa[a]	12,960
Euglena velata[a]	1,960
Gonium pectorale[b]	1,128
August 13	
Carteria sp.[a]	2,272
Eudorina elegans[b]	704
Thoracomonas phacotoides[a]	4,000
August 15	
Melosira granulata[b]	1,696
Thoracomonas phactoides[a]	17,920
August 31	
Eudorina elegans[b]	544
Melosira granulata[b]	3,872

Source: Lackey 1957, Table II.

[a]Unicellular flagellate.

[b]Colonial species.

relative abundance of certain groups (e.g., a shift in the abundance of the two major groups of green algae, from volvocales to chlorococcales), total cell densities are similar. These results suggest that phytoplankton population dynamics in the embayment are still greatly influenced by the populations in the lake (Fig. 4.8).

The phytoplankton community in the Clinch River immediately below Melton Hill Dam has not been described previously. Other studies were conducted downstream of the study area and the results were summarized previously (Loar, in press, Sect. 1.6.1).

Taxonomic composition

As mentioned above, the composition of the phytoplankton community near the mouth of White Oak Creek (Station WOCK 0.2) is influenced by the existence of an upstream impoundment (White Oak Lake). The dominant group was Chlorophyta, which included 37 genera and 78% of the phytoplankton abundance. The relative abundance of Chrysophyta at this site exceeded that found in the lake but was considerably lower than in the Clinch River. At these latter sites, the Chrysophyta composed more than 50% of the phytoplankton abundance, with diatoms alone accounting for about 33% of the total numbers. The order of abundance of the remaining four groups (Cryptophyta, Cyanophyta, Euglenophyta, and Pyrrophyta) was similar at all sites except White Oak Lake.

Seasonal distribution and abundance

The phytoplankton populations in both White Oak Creek embayment and the Clinch River exhibited several major pulses between April and October (Fig. 4.21). In the embayment, the largest pulse occurred in the spring (late April), about four to six weeks earlier than the initial pulse in the river. The delayed pulse at the two river sites was most likely due to water temperatures that were 3 to 4°C lower than in the creek from late April through May (Fig. 2.4).

The spring peak at station WOCK 0.2 was almost exclusively due to the presence of *Scenedesmus*, which reached a density of 11,098 units/ml in late April (Fig. 4.22). This peak coincided with the *Scenedesmus* bloom

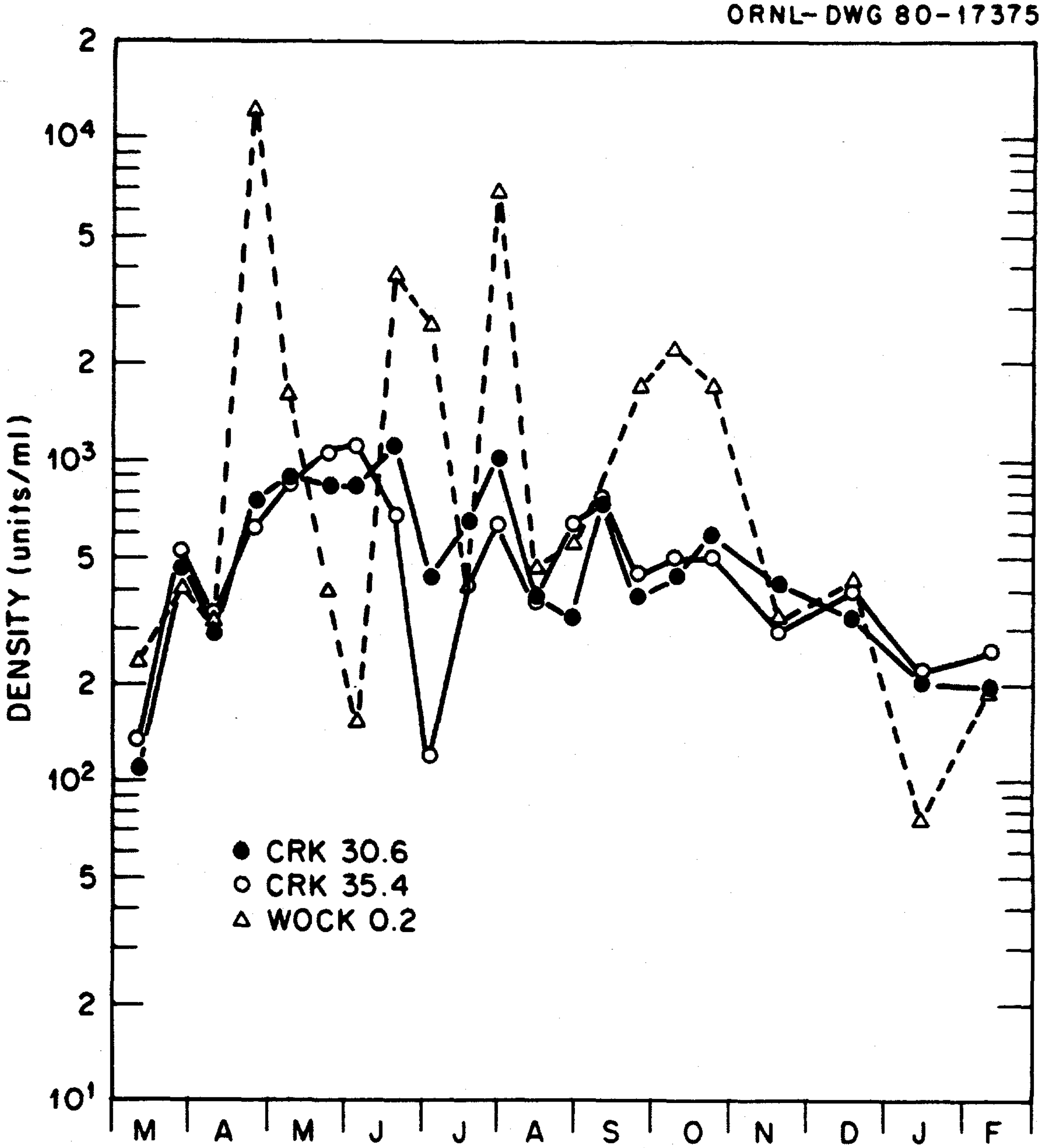

Fig. 4.21. Temporal fluctuations in total phytoplankton density (units/ml) in White Oak Creek embayment and the Clinch River, March 1979-February 1980. For colonial forms, 1 colony = 1 unit. CRK = Clinch River kilometer; WOCK = White Oak Creek kilometer.

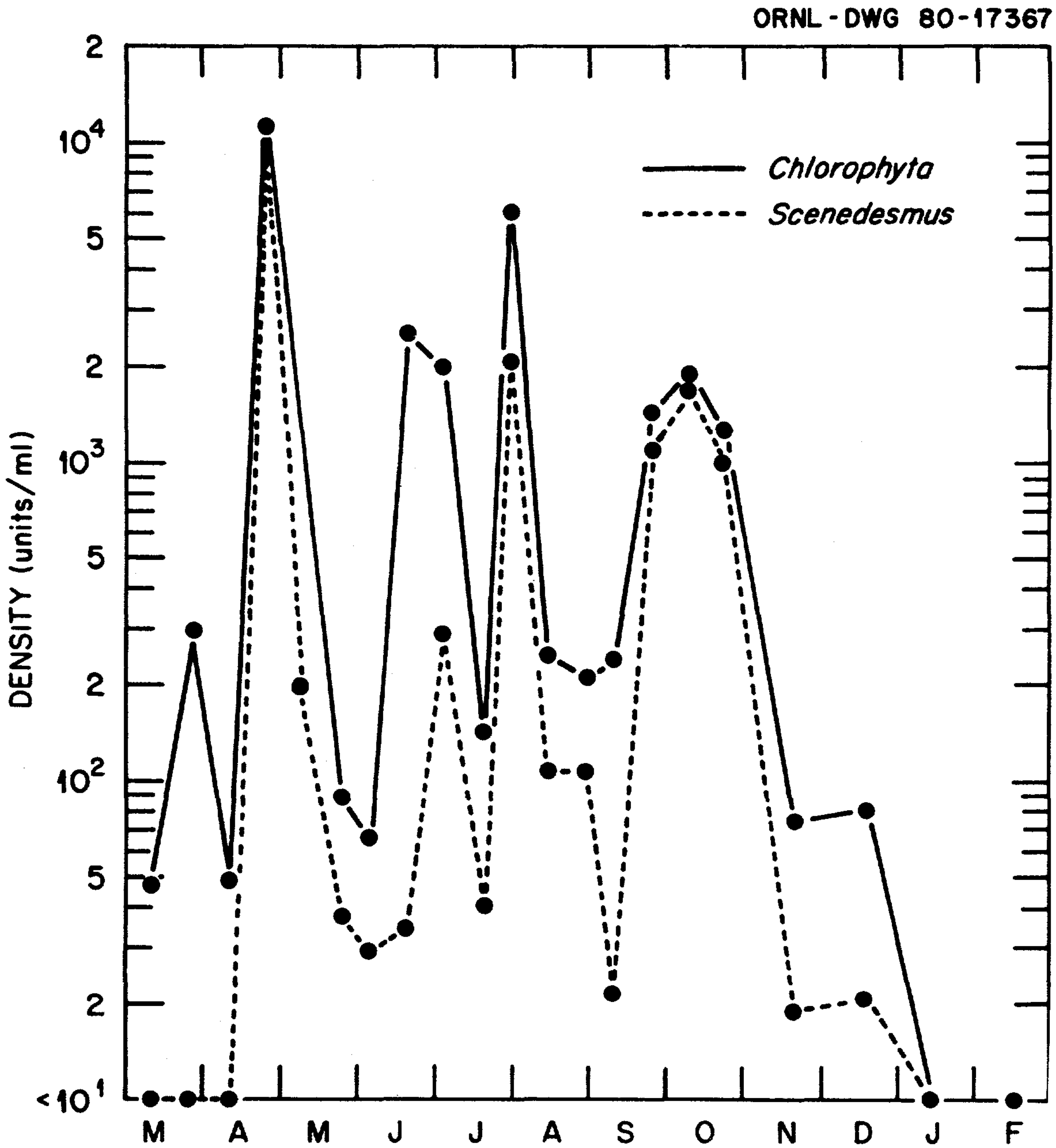

Fig. 4.22. Comparison of the temporal fluctuations in the density (units/ml) of total Chl^rophyta (all taxa combined) and *Scenedesmus* (Chlorophyta: Chlorococcales) at station White Oak Creek kilometer (WOCK) 0.2 in White Oak Creek embayment, March 1979–February 1980. For colonial forms, 1 colony = 1 unit.

in White Oak Lake (Fig. 4.10). The other abundant genus in the lake at this time was *Chlamydomonas*, which had a peak density of 11,203 cells/ml in early May. Below the lake, however, no bloom was observed and densities never exceeded 254 cells/ml in April and May.

Green algae were also the dominant group in the pulses that occurred at station WOCK 0.2 in the summer and fall (Figs. 4.21 and 4.22). The generic composition of these pulses was similar to that of the pulses that occurred in White Oak Lake at approximately the same time. For example, the peak abundance of *Schroederia* occurred in mid-June (1946 cells/ml), whereas the density of *Actinastrum* exhibited two peaks, one in early July (1013 colonies/ml) and a second about four weeks later (994 colonies/ml). Both genera composed the majority of the mid-summer pulse in White Oak Lake (Fig. 4.10). In both the lake and the embayment below the lake, *Scenedesmus* was present in varying proportions in each of these later pulses. The same genus was also abundant in Poplar Creek, where it reached a density of 6922 colonies/ml in August at a site above the Oak Ridge Gaseous Diffusion Plant (ORGDP) but below the East Fork Poplar Creek which receives effluent from the Y-12 plant and the Oak Ridge Sewage Treatment Plant (Loar, in press).

Small peaks in the abundance of other major groups occurred from April to October (Fig. 4.23) at station WOCK 0.2, but the peaks did not coincide as was observed in White Oak Lake (see Fig. 4.11). Maximum densities of diatoms occurred in late spring and, in general, preceded the period when other groups such as the Cryptophyta and Cyanophyta were abundant. The Euglenophyta were present during the spring and fall, but densities remained relatively low.

The seasonal pattern in phytoplankton abundance in the Clinch River was characterized by the dominance of diatoms during the spring at both CRK 30.6 (Fig. 4.24) and CRK 35.4 (Fig. 4.25). The most abundant genus at both sites during May and June was *Synedra*, with maximum densities of 378 and 329 cells/ml at CRK 30.6 and 35.4 respectively. Distinct diatom pulses consisting primarily of *S. delicatissima* were observed in August near CRK 24.1 during the 1977-78 ORGDP sampling program (Loar, in press). A shift in relative abundance to the Chlorophyta and Cryptophyta

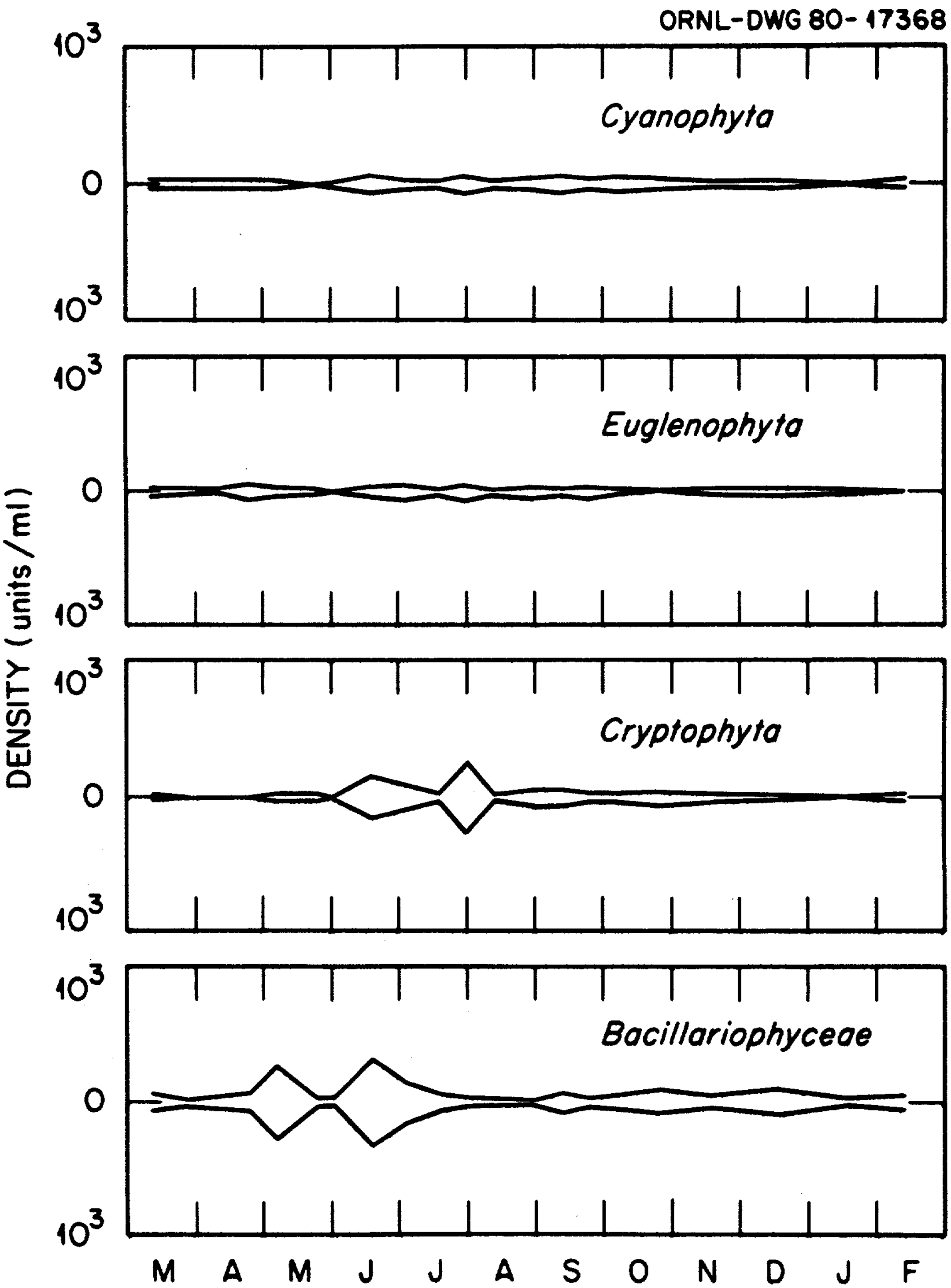

Fig. 4.23. Temporal distribution and abundance (units/ml) of the four major algal groups (Chlorophyta excluded) composing the phytoplankton community at station White Oak Creek kilometer (WOCK) 0.2 in White Oak Creek embayment, March 1979-February 1980. For colonial forms, 1 colony = 1 unit.

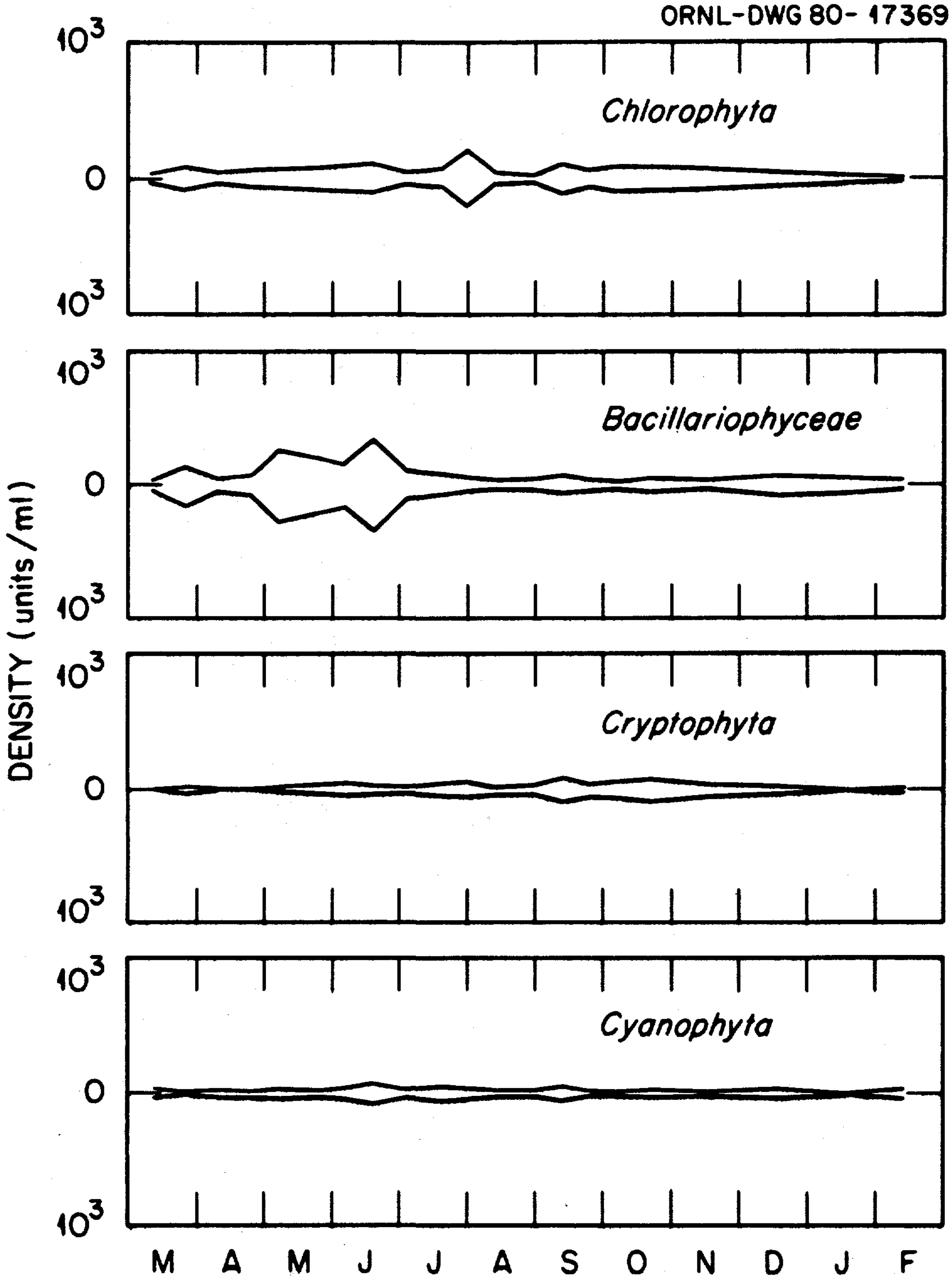

Fig. 4.24. Temporal distribution and abundance (units/ml) of the four major algal groups composing the phytoplankton community in the Clinch River near Clinch River kilometer (CRK) 30.6, March 1979-February 1980. The mouth of White Oak Creek is located at CRK 33.5. For colonial forms, 1 colony = 1 unit.

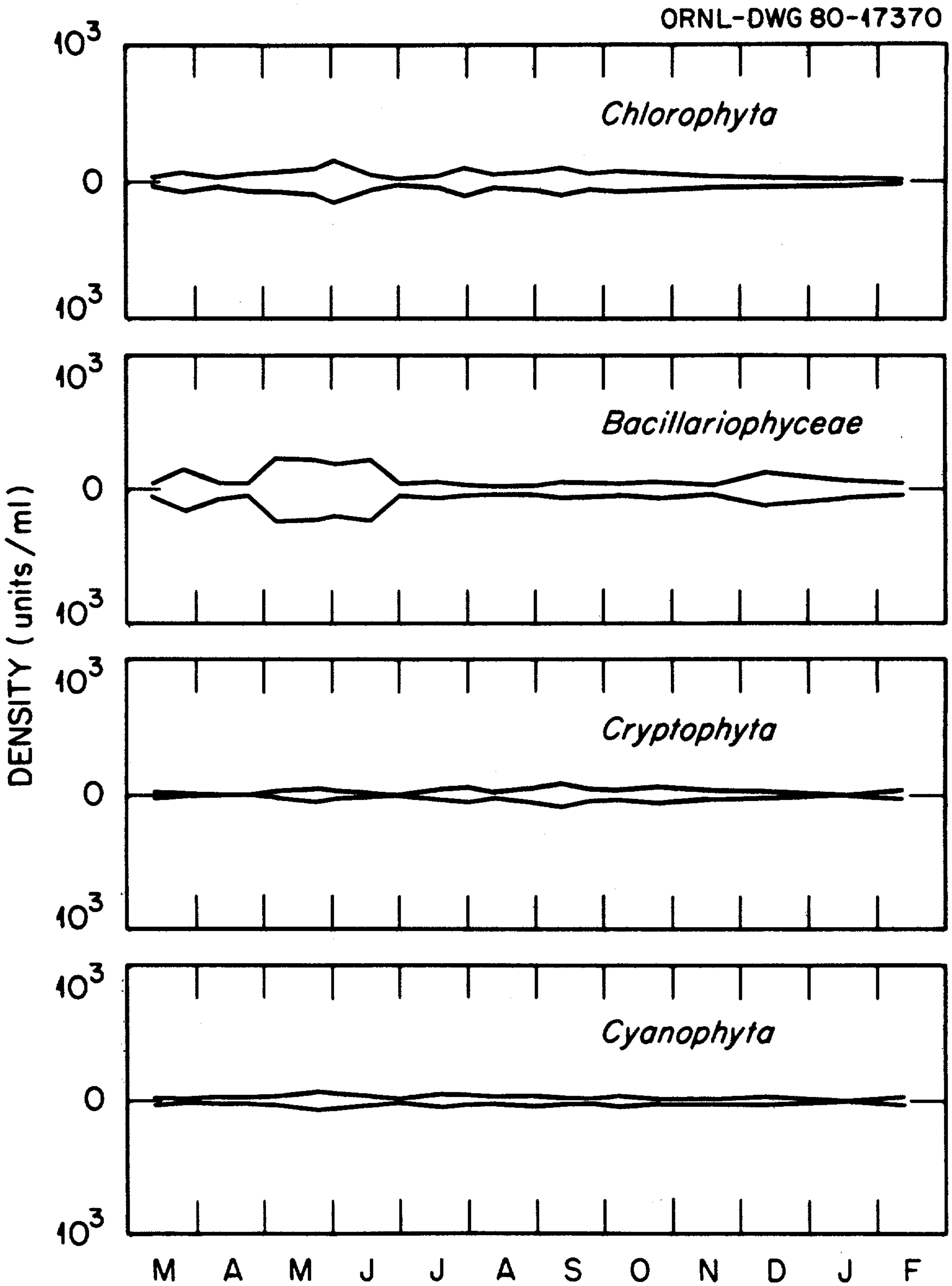

Fig. 4.25. Temporal distribution and abundance (units/ml) of the four major algal groups composing the phytoplankton community in the Clinch River near Clinch River kilometer (CRK) 35.4, March 1979–February 1980. The mouth of White Oak Creek is located at CRK 33.5. For colonial forms, 1 colony = 1 unit.

occurred during the summer and was followed by a return to a diatom-dominated community as water temperatures dropped in the fall.

Spatial distribution

The phytoplankton communities at the four sampling sites were compared using the Bray-Curtis dissimilarity index (Sect. 3.3). Coefficients of dissimilarity were calculated for each of six possible station pairs on each sampling date. Univariate analyses of variance were performed on these data in order to determine whether or not the communities at some of the sites were more similar than others throughout the year. The results of this analysis are presented in Table 4.13.

The relative ranking of the dissimilarity coefficients followed the pattern that would be expected based upon the location and type of habitat sampled. For example, the stations exhibiting the greatest degree of dissimilarity were WOCK 1.1 (White Oak Lake) and either of the two Clinch River sites (0.846 and 0.829). Because station WOCK 0.2 is located below White Oak Lake but is influenced by flows from the river, the phytoplankton community at this site could be expected to exhibit characteristics of both the lake and river communities. The communities at the two sampling sites located in relatively the same environment (the Clinch River) showed the greatest similarity (dissimilarity coefficient = 0.243).

The spatial distribution of the major groups of phytoplankton was also examined using a univariate analysis of variance (Table 4.14). For all groups except the diatoms, the densities in White Oak Lake were significantly higher ($p < 0.05$) than the densities in the Clinch River. Although the abundance of these groups in White Oak Creek embayment appeared to exceed that at the two river sites, only the difference in Chlorophyta density was significant at $\alpha = 0.05$.

Phytoplankton abundance at the two river sites was also examined by a multivariate analysis of variance. The densities of all seven groups (i.e., nondiatom Chrysophyta, Cryptophyta, and Pyrrophyta in addition to the four major groups mentioned previously) were used as response variables, and collection date was used as a blocking factor (Sect. 3.3). No significant differences in phytoplankton abundance between stations

Table 4.13. Comparison of the mean dissimilarity coefficients (± 1 standard error) for the phytoplankton communities between all station pairs

Tabular values were derived from coefficients computed separately for each sampling date, March 1979-February 1980. Means that do not have the same letter in their superscripts are significantly different ($p < 0.05$).

	WOCK 1.1[a]	WOCK 0.2	CRK 35.4[b]	CRK 30.6
WOCK 1.1		0.583^{a} (0.059)	0.846^{b} (0.030)	0.829^{b} (0.034)
WOCK 0.2			0.582^{a} (0.057)	0.567^{a} (0.052)
CRK 35.4				0.243^{c} (0.023)
CRK 30.6				

[a]White Oak Creek kilometer 1.1.

[b]Clinch River kilometer 35.4.

Table 4.14. Comparison of the geometric mean densities of the four major phytoplankton groups at four sampling sites, March 1979-February 1980

Values not connected by the same line are significantly different ($p < 0.05$). Station White Oak Creek kilometer (WOCK) 1.1 is located in White Oak Lake

	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Chlorophyta	1073	322	79	93
Chrysophyta (diatoms only)	85	113	130	135
Cyanophyta	53	33	18	22
Euglenophyta	60	21	14	15

[a]CRK = Clinch River kilometer 35.4.

CRK 35.4 and 30.6, located above and below the mouth of White Oak Creek (CRK 33.5), respectively, could be detected ($p > 0.30$).

4.3.2 Zooplankton

No previous studies have been conducted of the zooplankton communities in White Oak Creek embayment or the Clinch River immediately below Melton Hill Dam. Several past studies have described the zooplankton communities between CRK 28.8 and 16.9. The results of these studies have been summarized elsewhere (Loar, in press).

Taxonomic composition

The zooplankton community in White Oak Creek embayment (station WOCK 0.2) and the Clinch River (stations CRK 35.4 and 30.6) was dominated by the Rotifera which made 89, 91, and 94%, respectively, of all the zooplankton found at the three sites. The most abundant rotifer at each site was *Synchaeta* sp., a planktonic species. Other planktonic rotifers, including *Polyarthra* sp., *Keratella earlinae*, and *Asplanchna herricki*, were also abundant. Although densities of littoral species, such as *Lecane* sp. and *Monostyla*, were almost an order of magnitude higher in the creek than in the river, these two genera together made up less than 2% of rotifer abundance at station WOCK 0.2. The relative abundance of predatory rotifers (*Asplanchna*, *Synchaeta*, *Ploesoma*, and *Trichocerca*) ranged from 42 to 48% at the three sites, compared with less than 1% at station WOCK 1.1 in White Oak Lake.

The crustacean component of the zooplankton community at all three sites was dominated by copepods, most of which were nauplii (Fig. 4.12). The relative abundance of the other major group of crustacean zooplankton, the Cladocera, was about 30%, but the taxonomic composition of this group was different at the creek and river sites. In White Oak Creek embayment, the most abundant species were the same as those in the lake; *Moina micrura* and *Diaphanosoma leuchtenbergianum* made up 38 and 27%, respectively, of the cladocerans collected at this site. In the river, on the other hand, the dominant species was *Bosmina longirostris*, with a relative abundance of 70 and 72% at stations CRK 35.4 and 30.6 respectively.

Seasonal distribution and abundance

Three major peaks in zooplankton abundance were observed, and each occurred at approximately the same time at the three sites (Fig. 4.26). Each peak was comprised primarily of rotifers. The spring pulse at WOCK 0.2 was dominated by *Synchaeta* sp. and *Asplanchna herricki*, both of which exhibited maximum densities at this time (100.8 and 68.9 individuals/L respectively). Two other species, *Brachionus calyciflorus* and *Polyarthra* sp., also exhibited maxima in the spring. The spring pulse at CRK 35.4 was dominated by *A. herricki* (33.5 individuals/L), with *B. calyciflorus* and *Synchaeta* each composing 14% of the spring pulse. At CRK 30.6, *Polyarthra* was the most abundant rotifer (42.4 individuals/L). Three other species (*Synchaeta* sp., *A. herricki*, and *B. calyciflorus*) were also abundant and together accounted for 55% of the rotifer population in the spring.

Although *Synchaeta* sp. and *Polyarthra* sp. were also abundant in the mid-summer pulse in the Clinch River and White Oak Creek embayment, several other species that were either absent or present in very low numbers during the spring and late summer pulses exhibited maximum densities at this time. These species, which occurred at all three sites, included *Keratella cochlearis*, *Ploesoma truncata*, *Trichocerca* sp., and *Filinia longiseta*. Densities of *B. calyciflorus* and *A. herricki* were low, generally less than 5 individuals/L.

The strong pulse observed in late summer at CRK 30.6 was due to large numbers of *Synchaeta* sp. (180.0 individuals/L). Two other species, *Keratella crassa* (73.0 individuals/L) and *A. herricki* (64.7 individuals/L), also exhibited seasonal maxima at this time. The composition of the late summer peak at stations WOCK 0.2 and CRK 35.4 was similar to that at CRK 30.6, but densities were considerably lower.

The crustacean zooplankton populations also exhibited several pulses from May to October. At station WOCK 0.2, the major peak in cladoceran abundance occurred in the spring (Fig. 4.27). Densities of *Diaphanosoma leuchtenbergianum* reached a maximum of 7.7 individuals/L in late May, while densities of *Moina micrura* did not peak until mid-June (10.2 individuals/L). Fluctuations in the density of nauplii were responsible

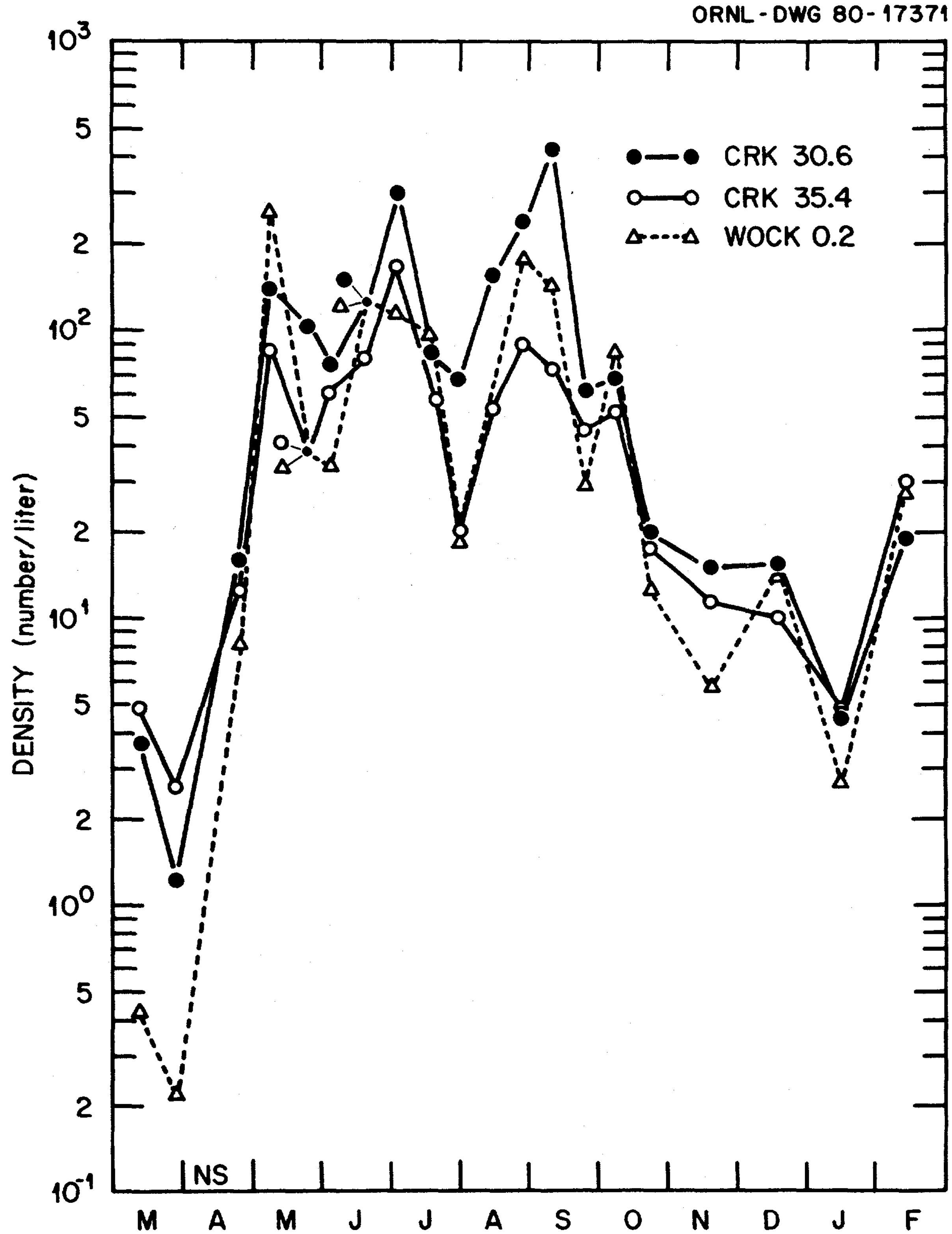

Fig. 4.26. Temporal fluctuations in total zooplankton densities (number per liter) at station White Oak Creek kilometer (WOCK) 0.2 in White Oak Creek embayment and at two sites in the Clinch River, March 1979-February 1980. NS = no samples. CRK = Clinch River kilometer.

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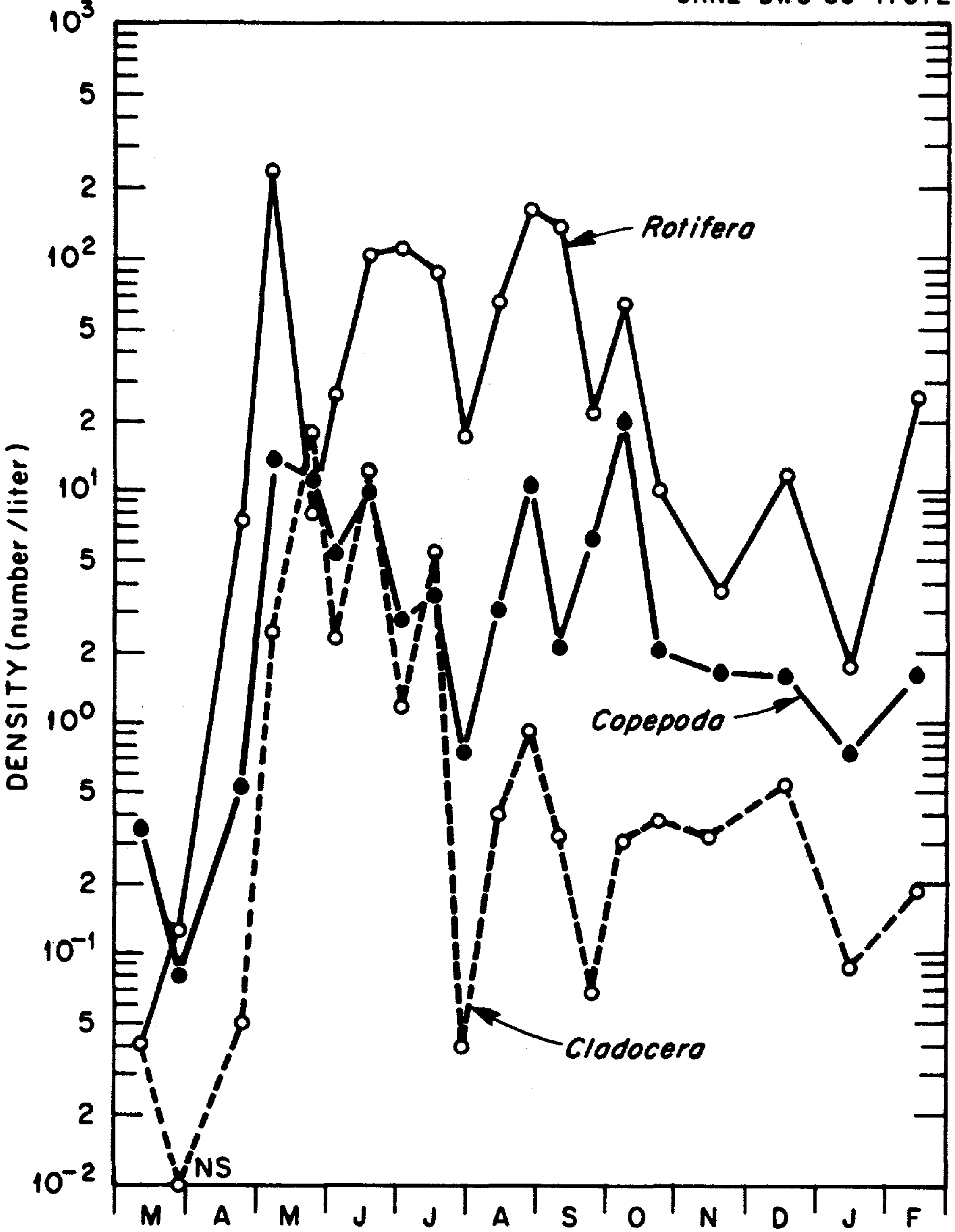

Fig. 4.27. Temporal fluctuations in rotifer, cladoceran, and copepod densities (number per liter) at station White Oak Creek kilometer (WOCK) 0.2 in White Oak Creek embayment, March 1979–February 1980. NS = no samples.

for the seasonal patterns in copepod abundance that occurred in both White Oak Creek embayment and the Clinch River.

That a single species, *Bosmina longirostris*, dominated the cladoceran population in the Clinch River may account for the dampened fluctuations in abundance and the occurrence of a single well-defined spring peak (Figs. 4.28 and 4.29). Densities of *B. longirostris* reached a maximum of 6.8 individuals/L at CRK 30.6 and 6.7 individuals/L at CRK 35.4 in late May. Several minor fluctuations in the density of both copepods and cladocerans were observed in late summer and fall, but were more pronounced at station CRK 30.6 below the mouth of White Oak Creek than at the upstream station.

Spatial distribution

The spatial distribution of zooplankton was examined by the same procedure used for phytoplankton, with generally the same results (Table 4.15). The only difference in the spatial distribution patterns of these two communities was that the zooplankton community in White Oak Creek embayment was more similar to the communities in the Clinch River than to the community in White Oak Lake. Because the number of sampling dates differed between these two sets of comparisons ($n = 21$ and $n = 14$ respectively; see Sect. 3.1), these results may be misleading. Only minimal sampling bias was introduced in the comparisons for the phytoplankton communities ($n = 21$ and $n = 20$ for the comparison of station WOCK 0.2 with the lake and river sites respectively).

Univariate analyses of variance were used to compare the densities of the three major groups of zooplankton among the four sampling sites (Table 4.16). Although the densities of all three major groups appeared lower in White Oak Lake, the occurrence of significantly lower ($p < 0.05$) densities of rotifers, the dominant group at all sites, is of particular interest. Based upon the high abundance of phytoplankton (especially nannoplankton) in the lake, correspondingly high densities of rotifers (which utilize these small organisms) could have been expected. The rotifer assemblage in the lake is primarily composed of littoral species, but the community at the other sites primarily consists of planktonic

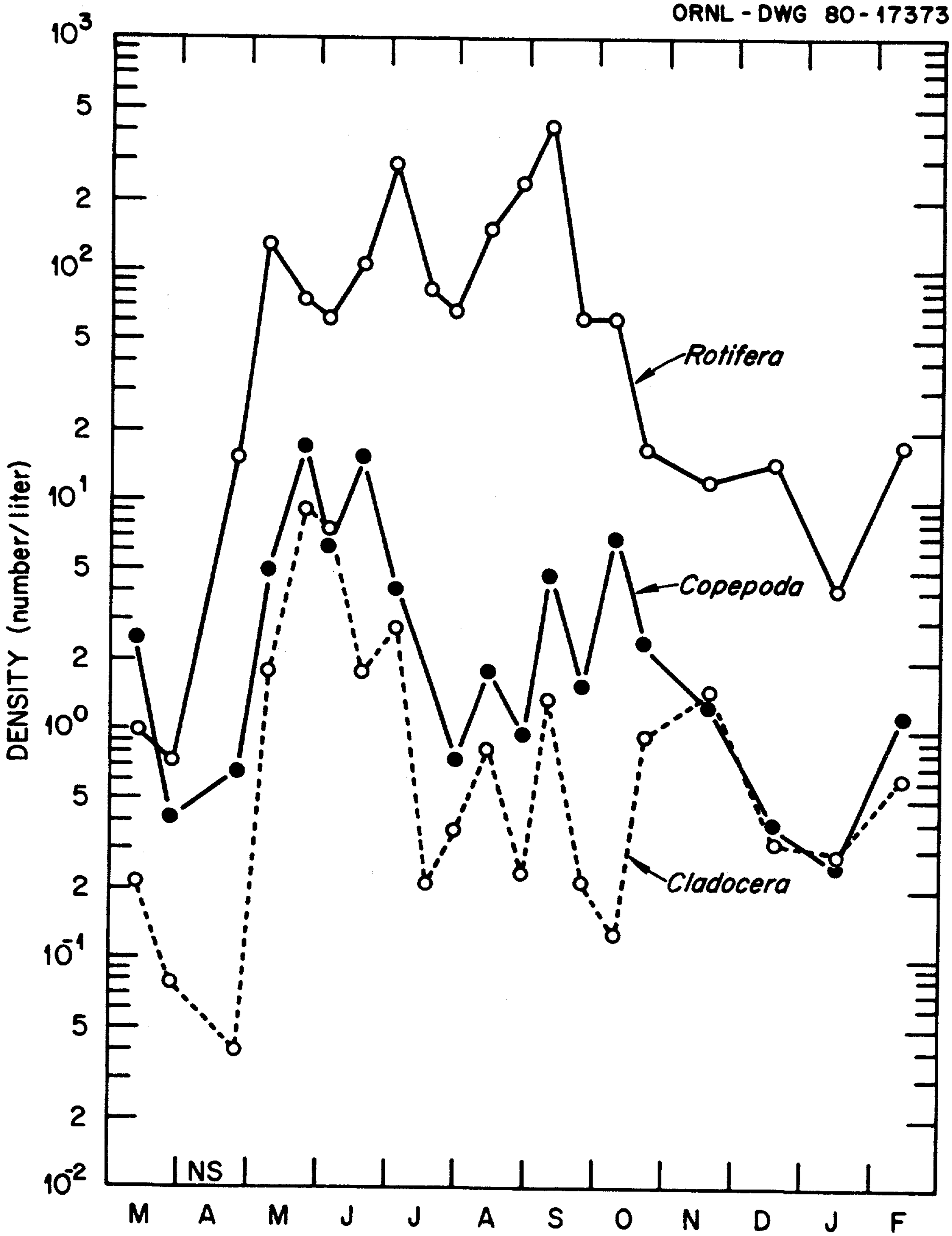

Fig. 4.28. Temporal fluctuations in rotifer, cladoceran, and copepod densities (number per liter) at station Clinch River kilometer (CRK) 30.6 in the Clinch River below the mouth of White Oak Creek (CRK 33.5), March 1979–February 1980. NS = no samples.

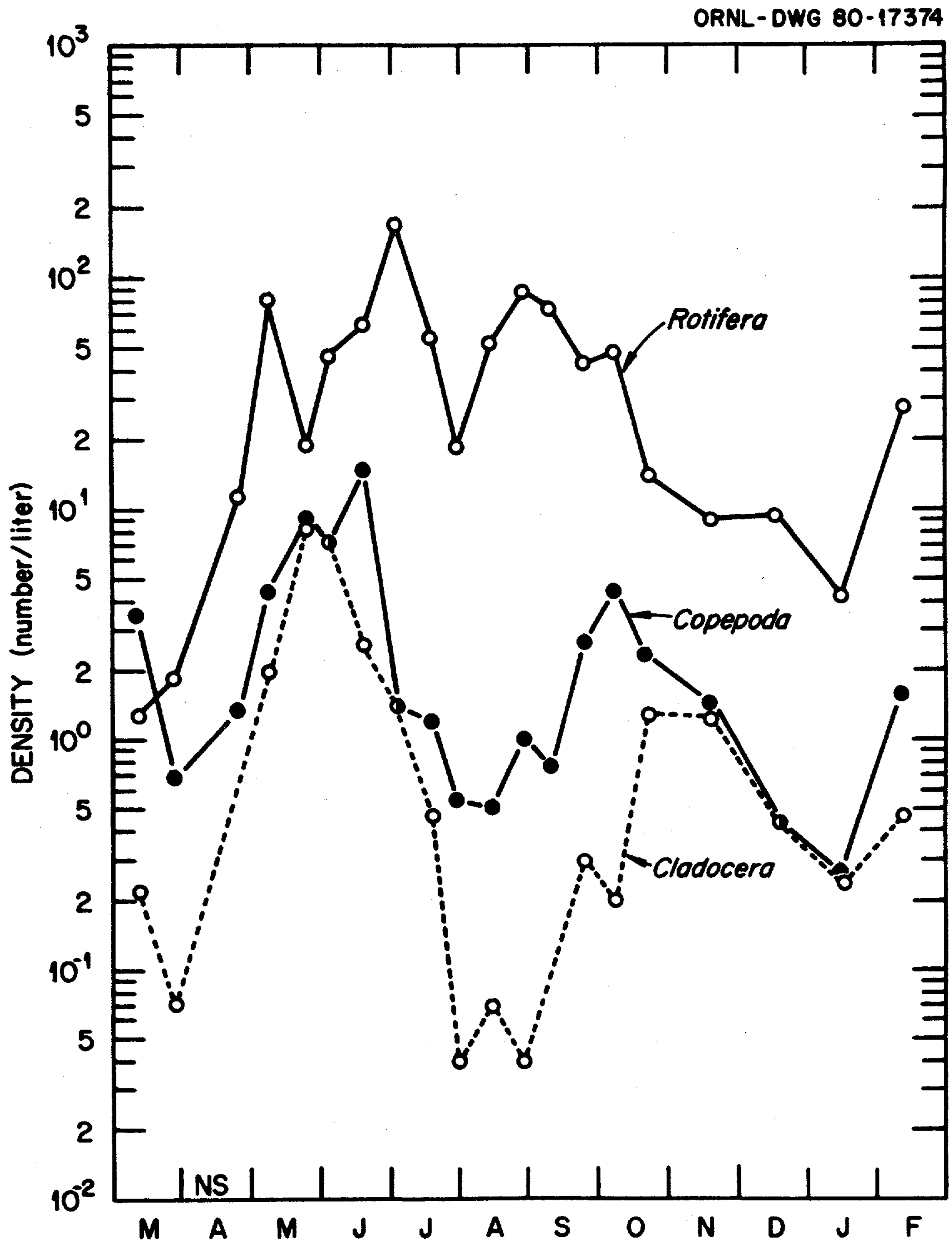

Fig. 4.29. Temporal fluctuations in rotifer, cladoceran, and copepod densities (number per liter) at station Clinch River kilometer (CRK) 35.4 in the Clinch River above the mouth of White Oak Creek (CRK 33.5), March 1979-February 1980. NS = no samples.

Table 4.15. Comparison of the mean coefficients of dissimilarity (± 1 standard error) for the zooplankton communities between all station pairs

Tabular values were derived from coefficients computed separately for each sampling date, March 1979-February 1980.[a] Means that do not have the same letter in their superscripts are significantly different ($p < 0.05$).

	WOCK 1.1[b]	WOCK 0.2	CRK 35.4[c]	CRK 30.6
WOCK 1.1		0.743^{b} (0.033)	0.885^{c} (0.018)	0.909^{c} (0.012)
WOCK 0.2			0.481^{d} (0.052)	0.510^{d} (0.047)
CRK 35.4				0.334^{e} (0.039)
CRK 30.6				

[a]March-November 1979 at station WOCK 1.1 (Sect. 3.1).

[b]White Oak Creek kilometer 1.1.

[c]Clinch River kilometer 35.4.

Table 4.16. Comparison of the geometric mean densities of the three major zooplankton groups at four sampling sites, March 1979-February 1980.[a]

Values not connected by the same line are significantly different ($p < 0.05$). Station White Oak Creek kilometer (WOCK) 1.1 is located in White Oak Lake

	WOCK 1.1	WOCK 0.2	CRK 35.4[b]	CRK 30.6
Cladocera	136	337	281	472
Copepoda	6	10	9	11
Rotifera	2,297	13,491	15,994	24,341

[a]March-November 1979 at station WOCK 1.1 (see Sect. 3.1).

[b]Clinch River kilometer.

species. Consequently, comparisons of the rotifer communities between sites which represent distinctly different types of habitats may not be entirely valid.

No significant differences were found between the densities of the three zooplankton groups at the stations in White Oak Creek embayment and the Clinch River (Table 4.16). A more sensitive analytical method (multivariate ANOVA) was employed in the comparison of zooplankton abundance at the two Clinch River sites which were located above and below the confluence with White Oak Creek. Using the abundances of the three major groups as response variables, no significant differences were detected between the two stations ($p > 0.10$).

4.3.3 Ichthyoplankton

Compared to White Oak Lake and upper White Oak Creek, ichthyoplankton samples taken from the Clinch River (CRK 30.6 and 35.4) had a larger number of fish taxa. In addition to unidentified fish eggs, larval *Aplodinotus grunniens*, Catostomidae, Clupeidae, Cyprinidae, *Cyprinus carpio*, *Lepomis*, *Morone*, and *Pomoxis* were collected at these stations.

Fish eggs were first collected from the Clinch River on April 24, 1978 (Fig. 4.30). By the end of April, Clupeidae larvae appeared in the samples and thereafter were collected on all sampling dates from May 24 through September 10. Clupeids were the most abundant ichthyoplankton found at CRK 35.4 and 30.6, reaching peak densities at both stations on June 12 and July 31 (Figs. 4.30 and 4.31). The first clupeid collections (April 30) contained only 4- and 5-mm TL yolk sac larvae, but post-yolk sac larvae ranging from 6 to 17 mm TL were found in subsequent samples.

Morone larvae were also found in the April 30, 1979, ichthyoplankton samples, and occasionally appeared in the collections until early July. *Pomoxis*, Cyprinidae, *Cyprinus carpio*, and Catostomidae larvae were collected in the Clinch River in late May and early June. *Aplodinotus grunniens* eggs were collected throughout June and July, but larvae of this species were found only in mid- to late June. *Lepomis* larvae appeared in the Clinch River samples on two widely separated dates, i.e., at CRK 35.4 on May 29 and at CRK 30.6 on July 31.

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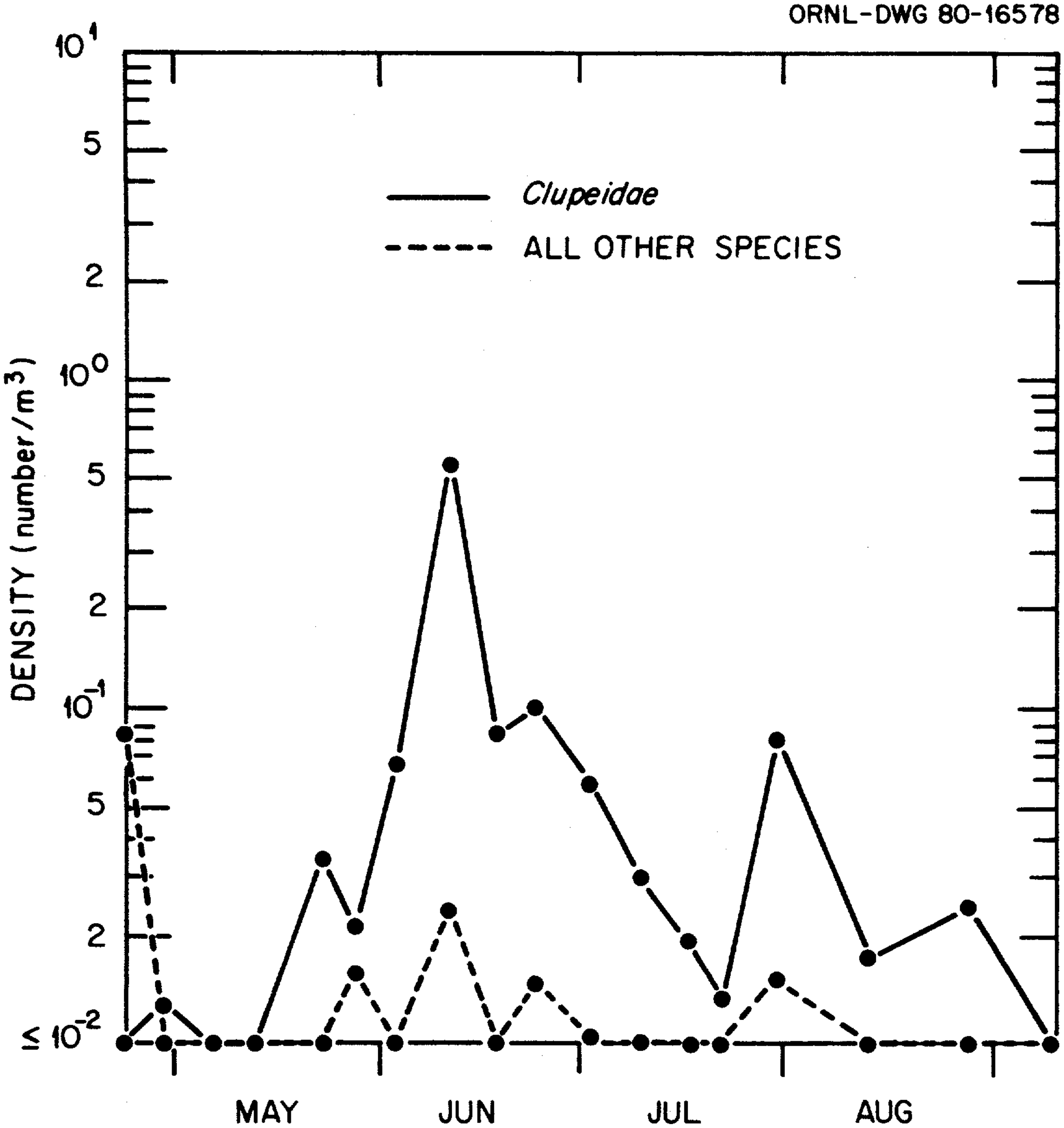

Fig. 4.30. Seasonal density patterns (arithmetic means of two replicates) of fish larvae in the Clinch River (station CRK 35.4), 1979.

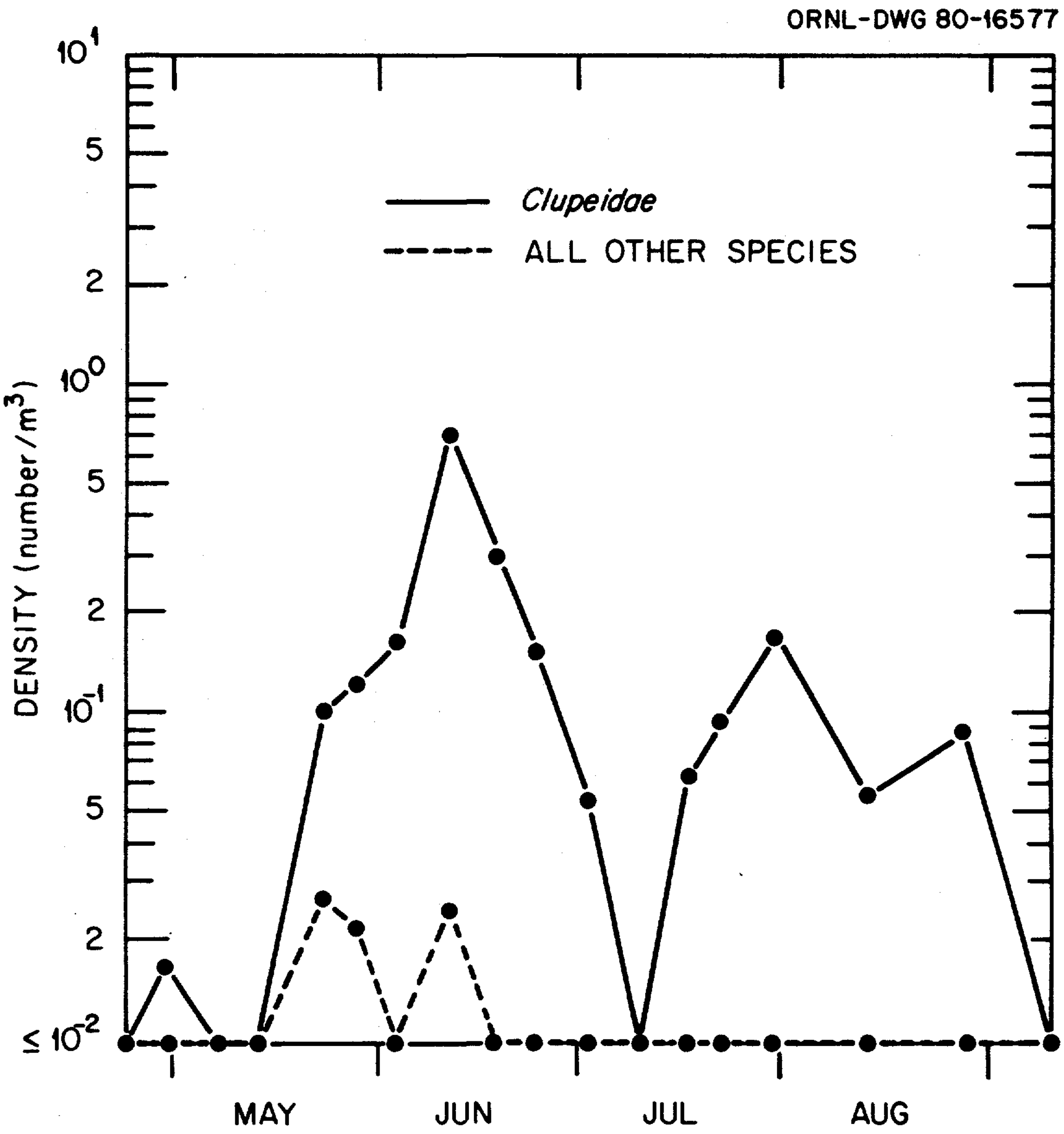

Fig. 4.31. Seasonal density patterns (arithmetic means of two replicates) of fish larvae in the Clinch River (station CRK 30.6), 1979.

The 36 pump samples taken in the White Oak Creek embayment of the Clinch River (WOCK 0.2) were dominated by unidentified fish eggs and Clupeidae larvae. Three egg density peaks were observed at WOCK 0.2 and were followed in each case by similar peaks in clupeid larvae (Fig. 4.32). Therefore, it is probable that the unidentified eggs were clupeid eggs. Further, since egg densities at WOCK 0.2 were generally more than an order of magnitude higher than densities observed in either White Oak Lake or the Clinch River, it is likely that the eggs were products of local spawning in the embayment rather than having drifted in from other areas.

The different method of sampling used at WOCK 0.2 should not have had a great effect on the densities of fish eggs collected, but the potential ability of motile larvae to avoid a pump intake or a net to different degrees may reduce the comparability of ichthyoplankton samples taken at different stations in this survey. No fish larvae larger than 6-mm TL were collected with the pump sampler used at WOCK 0.2, but it is not known whether this fact is related to the ability of larger larvae to avoid the low-velocity pump intake or to a short residency time of larvae in the White Oak Creek embayment.

The only other ichthyoplankton collected at WOCK 0.2 were three 5-mm TL *Lepomis* larvae found on June 1, 1979. This followed an observed peak in *Lepomis* larvae densities in White Oak Lake (Fig. 4.16), and these fish may have been washed out of the lake into the White Oak Creek embayment. Although adult carp were observed spawning, and although unidentified eggs (possibly carp) were collected at WOCK 0.2 on June 8, 1979, no carp larvae were recovered in the ichthyoplankton samples then or on subsequent days.

4.3.4 Periphyton

Previous studies

The only previous studies of the periphyton communities in the lower Clinch River were conducted below CRK 28. During the 1974-75 baseline aquatic survey conducted between CRK 28.8 and 24.1 near the proposed site of the Clinch River Breeder Reactor Project, periphyton biomass was measured on five dates between May 1974 and May 1975. Biomass, as ash-free dry

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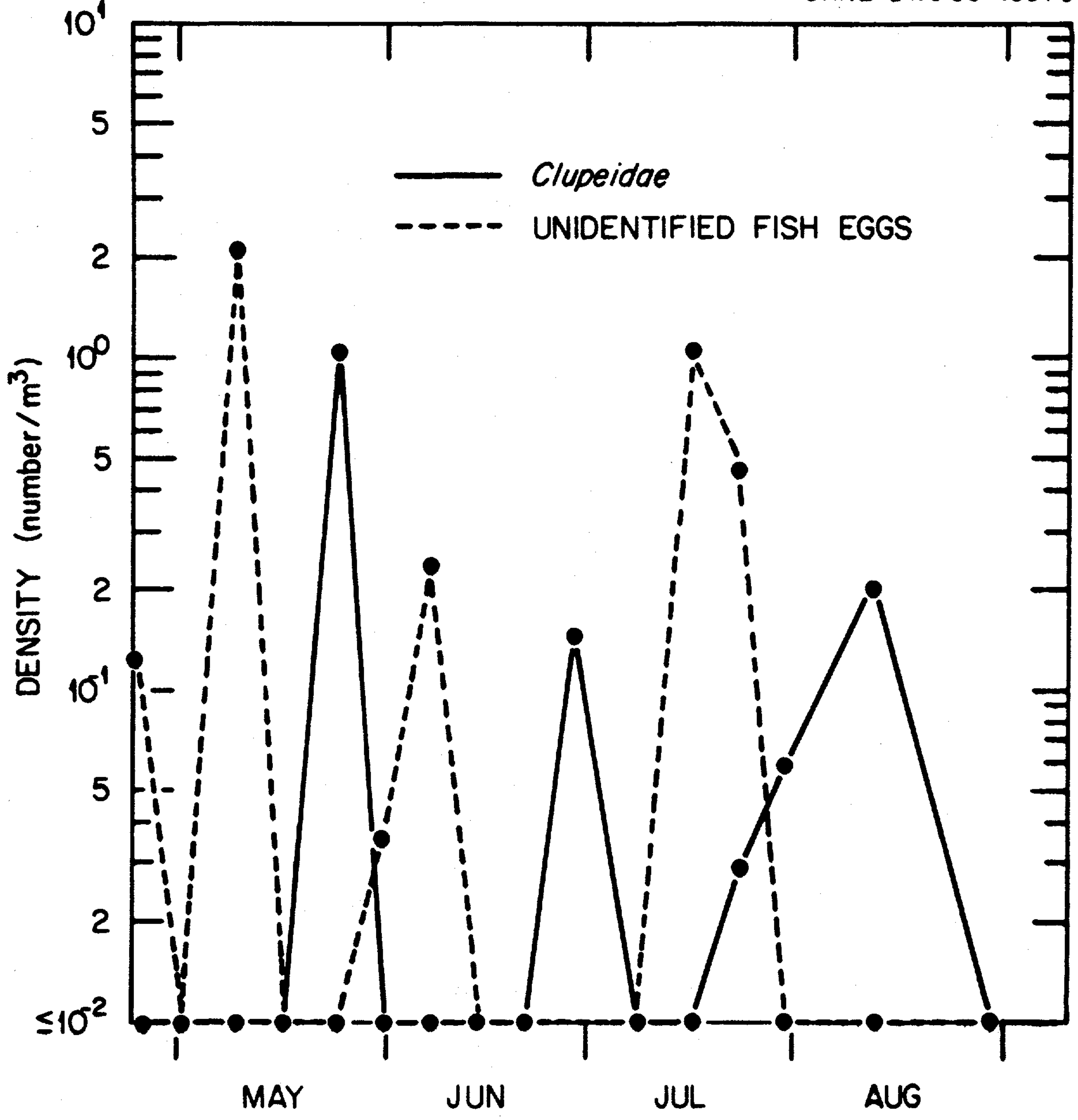

Fig. 4.32. Seasonal density patterns (arithmetic means of two replicates) of Clupeidae larvae and fish eggs in the White Oak Creek embayment [station White Oak Creek kilometer (WOCK) 0.2], 1979.

weight, ranged from 1447 mg/m^2 in early August to 19,913 mg/m^2 in May. Minimum and maximum chlorophyll a values, which also occurred in these months, were 8.41 mg/m^2 and 51.32 mg/m^2. The autotrophic index ranged from 76.7 (January) to 504.0 (May) (Project Management Corporation 1975, Table 2.7-70). Because of differences in the counting procedures used in this survey and the present study, comparisons of cell densities and taxonomic composition between the two studies cannot be made (Loar, in press, Sect. 1.6.2).

Periphyton sampling was also conducted in the Clinch River in the vicinity of Poplar Creek from September 1975 to August 1976 (Exxon Nuclear Company, Inc., 1976) and again between June 1977 and March 1978 (Loar, in press). Waste effluents from operation of ORGDP are discharged directly to the Clinch River near CRK 23.2 and 18.2 and to Poplar Creek, which joins the Clinch River at CRK 19.3. Since periphyton growth can be influenced by changes in water quality, the communities found in this region of the river would not provide a basis for comparison with the communities found just below Melton Hill Dam during the present survey.

Taxonomic composition

Diatoms made up 87% of the total periphyton at station WOCK 0.1 and 97 and 98% of the total numbers in the Clinch River near CRK 35.4 and 30.6 respectively. The dominant taxon was *Achnanthes*, which accounted for 96 and 91% of the diatoms at these latter sites. In White Oak Creek embayment, however, this taxon represented only 63% of the diatoms. Other abundant diatoms included *Navicula* (17%) and *Cymbella* (11%), both of which were also abundant in White Oak Lake (Sect. 4.2.4).

The dominant green algae at both Clinch River sites was *Stigeoclonium*, which made up 93 and 79% of the Chlorophyta at stations CRK 35.4 and 30.6 respectively. In White Oak Creek embayment, however, *Ankistrodesmus* was the most abundant taxon (65%), with *Stigeoclonium* representing only 20% of all the Chlorophyta at this site. The dominant blue-green algae in the Clinch River was *Lyngbya* at CRK 35.4 (94% of all of the Cyanophyta), and *Oscillatoria* (61%) and *Lyngbya* (32%) at CRK 30.6. Blue-green algae were twice as abundant at station WOCK 0.2 as either of the two river sites, and were represented by two dominant genera, *Oscillatoria* (45%) and *Lyngbya* (38%).

Spatial and temporal patterns exhibited by three measures of periphyton abundance (cell counts, biomass, and chlorophyll a) are discussed below.

Cell counts

Diatom abundance at station CRK 30.6 increased initially and then declined from August to January (Fig. 4.33). The sharp increase at this site in early March was due to both an increase in the density of *Gomphonema* from 39 units/cm^2 in January to 63,907 units/cm^2 in March, and to *Synedra*, which increased from 514 units/cm^2 to 40,362 units/cm^2 over the same period. Although *Achnanthes* was abundant throughout the summer, it declined in abundance during the winter. From January to March, the density of *Achnanthes* increased from 301 units/cm^2 to 22,358 units/cm^2. A period of declining densities was also observed at the two other sites, but patterns were not well defined because of missing samples (Sect. 3.1). No significant differences in diatom densities were detected among the three sampling sites ($p > 0.05$).

Densities of Chlorophyta reached a peak of 23,740 units/cm^2 in October at CRK 30.6 and 24,533 units/cm^2 in August (22,357 units/cm^2 in October) at CRK 35.4. In White Oak Creek embayment, Chlorophyta densities reached a peak in September of 55,537 units/cm^2 and then decreased throughout the remainder of the sampling program. No significant differences in Chlorophyta densities were found between the three stations ($p > 0.05$). Maximum densities of blue-green algae occurred in September at stations WOCK 0.2 and CRK 35.4 (2353 units/cm^2 and 1582 units/cm^2 respectively). At CRK 30.6, blue-green algae gradually increased in abundance throughout the summer and reached a peak of 1484 units/cm^2 in late fall.

Biomass

Temporal fluctuations in biomass exhibited a pattern different from that observed for diatom cell densities (Fig. 4.34). Sharp peaks in biomass were observed at each site but at different times. The greatest

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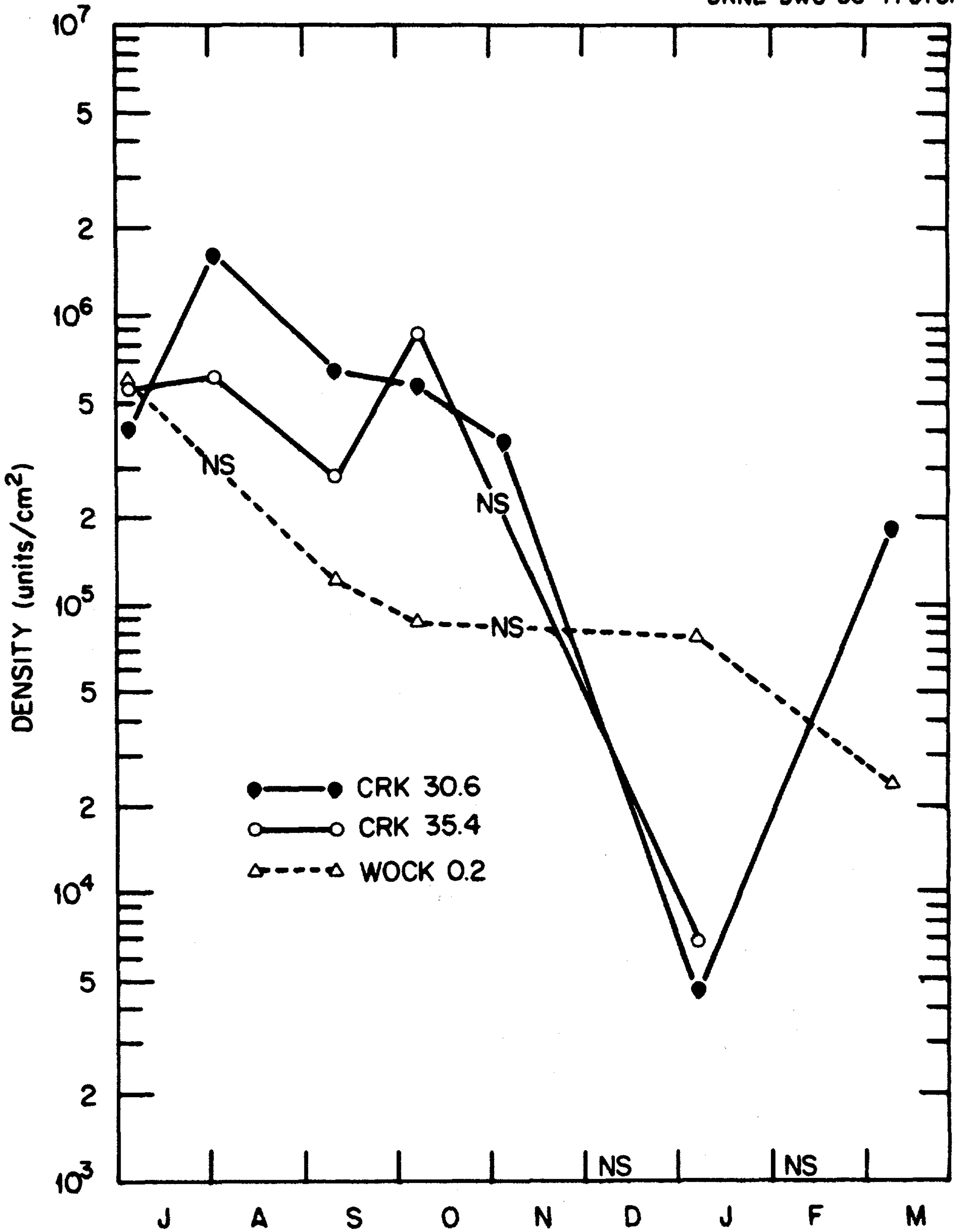

Fig. 4.33. Temporal fluctuations in the density of diatoms (units/cm^2) on plexiglass slides in White Oak Creek embayment [White Oak Creek kilometer (WOCK) 0.2] and the Clinch River above [Clinch River kilometer (CRK) 35.4] and below (CRK 30.6) the mouth of White Oak Creek at CRK 33.5, July 1979–March 1980. Dates shown on the graph represent the last day of the 28-d colonization period. For colonial forms, 1 colony = 1 unit. NS = no samples.

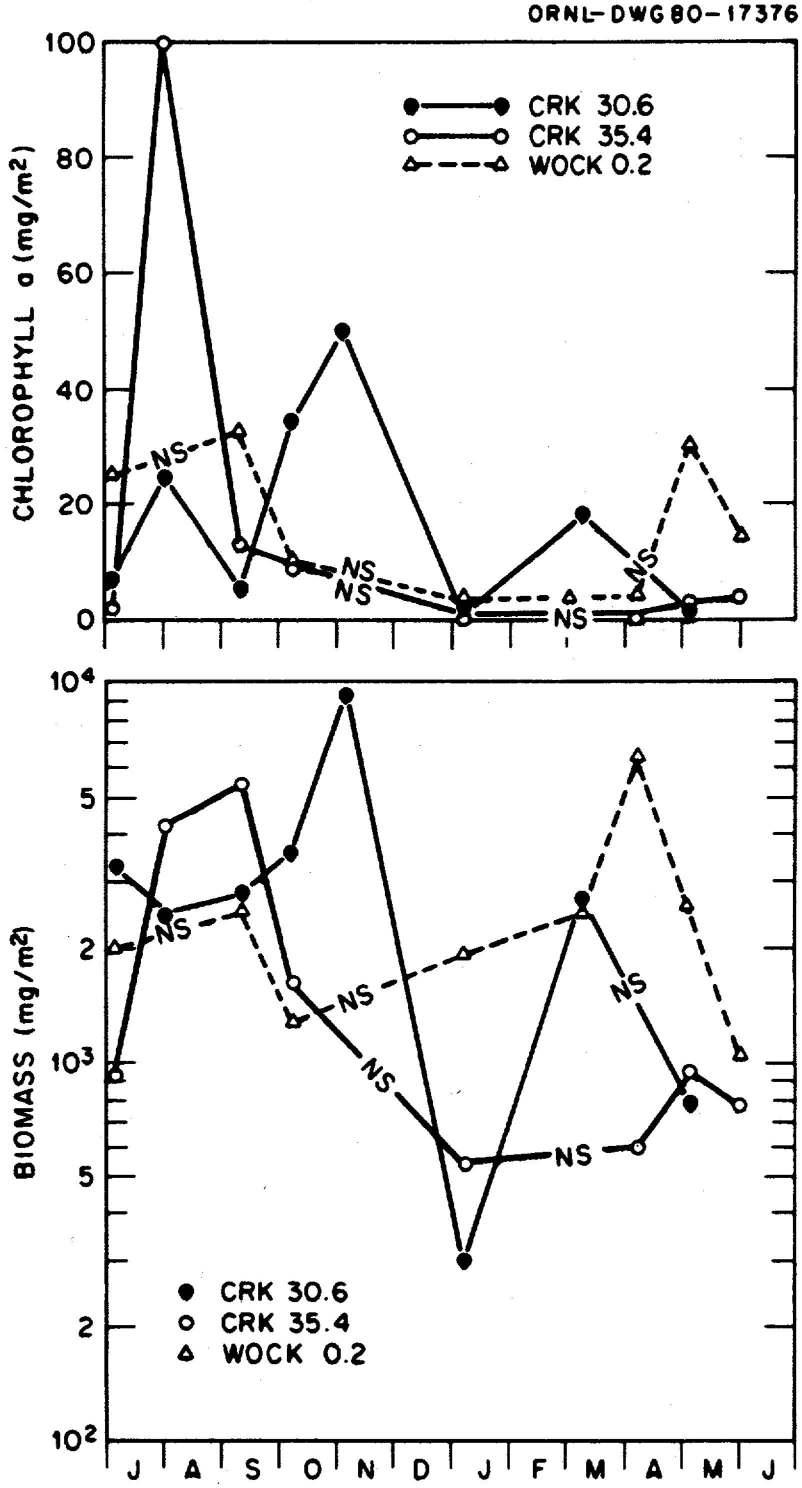

Fig. 4.34. Temporal fluctuations in chlorophyll a (mg/m^2) and biomass (mg/m^2) of periphyton on plexiglass slides in White Oak Creek embayment [White Oak Creek kilometer (WOCK) 0.2] and the Clinch River above [Clinch River kilometer (CRK) 35.4] and below (CRK 30.6) the mouth of White Oak Creek at CRK 33.5, July 1979–March 1980. Dates shown on the graph represent the last day of the 28-d colonization period. For colonial forms, 1 colony = 1 unit. NS = no samples.

increase in biomass occurred between October and November at station CRK 30.6. During the same period, diatom densities decreased (Fig. 4.33), primarily because of a decline in the density of *Achnanthes* from 546,874 to 300,049 units/cm^2. The increase in periphyton biomass but decrease in cell numbers over the same period may be, in part, due to a fourfold increase in the density of *Oscillatoria*, a filamentous blue-green. An increase in the abundance of filamentous forms could result in higher biomass but insignificant changes in cell densities, since one filament was equivalent to one unit. The size of the filament is not considered in the estimates of abundance based on direct counts.

Estimates of periphyton biomass at the two Clinch River sites were similar to those reported previously from an area of the river just downstream from CRK 30.6 (Project Management Corporation 1975). The statistical analysis of biomass at the three ORNL sampling sites detected no significant differences among these sites ($p > 0.05$).

Chlorophyll a

In general, the temporal trend in chlorophyll a values was similar to that observed for biomass (Fig. 4.34). An obvious exception, however, was the sharp increase in chlorophyll a between July and August at station CRK 35.4. The August peak at this site (100.16 mg/m^2) was more than twice as great as the peaks observed at the other sites and the peak that occurred during the 1974-75 Clinch River Breeder Reactor survey (Project Management Corporation 1975, Table 2.7-70). During this period, the densities of *Cymbella* increased twentyfold (to 22,753 units/cm^2), and the densities of *Stigeoclonium*, *Synedra*, and *Melosira* increased by a factor of 10. The dominant genus was *Achnanthes* during both sampling periods, but the density remained relatively unchanged (560,784 units/cm^2 and 570,222 units/cm^2 in July and August respectively). No significant differences in chlorophyll a were found among the three sampling stations ($p > 0.05$).

Maximum values of the autotrophic index occurred in White Oak Creek embayment in April (AI = 1544.7) and the annual mean at this site ($\overline{AI}$ = 459.3; n = 8) was higher than that at station CRK 35.4 ($\overline{AI}$ = 365.8; n = 8) or CRK 30.6 ($\overline{AI}$ 320.4; n = 8). For a given date, however, the AI value at WOCK 0.2 generally exceeded that in the river only during the winter and early spring; at other times, the highest values were found at the river sites (Fig. 4.35).

4.3.5 Benthic macroinvertebrates

Previous studies

In 1974-75, limited sampling was conducted on two occasions at a site in the immediate vicinity of station WOCK 0.2. Although total densities (all taxa combined) were low (<30 organisms/0.1 m^2), the abundance of *Hexagenia* sp. was relatively high (Table 4.17). This species made up 44% of all the total individuals collected at this site. Relatively low total densities were also observed in 1979-80, but no *Hexagenia* were collected. The only mayfly found in these samples was identified as *Caenis*, and densities in the December and February samples (none were collected at other times) were 9.5 and 7.8 individuals/0.1 m^2 respectively.

No previous surveys have been made of the benthic macroinvertebrate community in the Clinch River between Melton Hill Dam (CRK 37.2) and CRK 28.8. Mollusks, however, were qualitatively sampled in small tributaries of the Clinch River in 1961, two years before Melton Hill Dam was completed, and several species were reported from two streams near the mouth of White Oak Creek (Table 4.4). In addition, several studies were conducted just below the study area at various sites between CRK 16.9 and 28.8 (Project Management Corporation 1975; Exxon Nuclear Company, Inc., 1976; Loar, in press). A survey of the benthic community in the Clinch River above and below Poplar Creek was conducted between April 1977 and March 1978 using the same methods and sampling frequencies similar to those in the present survey (Loar, in press, Sect. 1.6.4). The mean density, averaged over all months, ranged from 41.2 to 79.8 organisms/0.1 m^2 among the three sites. At all sites the peak density (70.4 to 129.3 organisms/0.1 m^2) occurred in September. The dominant taxa were representatives of the orders Oligochaeta (45% of the organisms collected), Diptera (26%), and Pelecypoda, primarily *Corbicula manilensis* (22%). Results similar to these were obtained during the 1979-80 ORNL survey.

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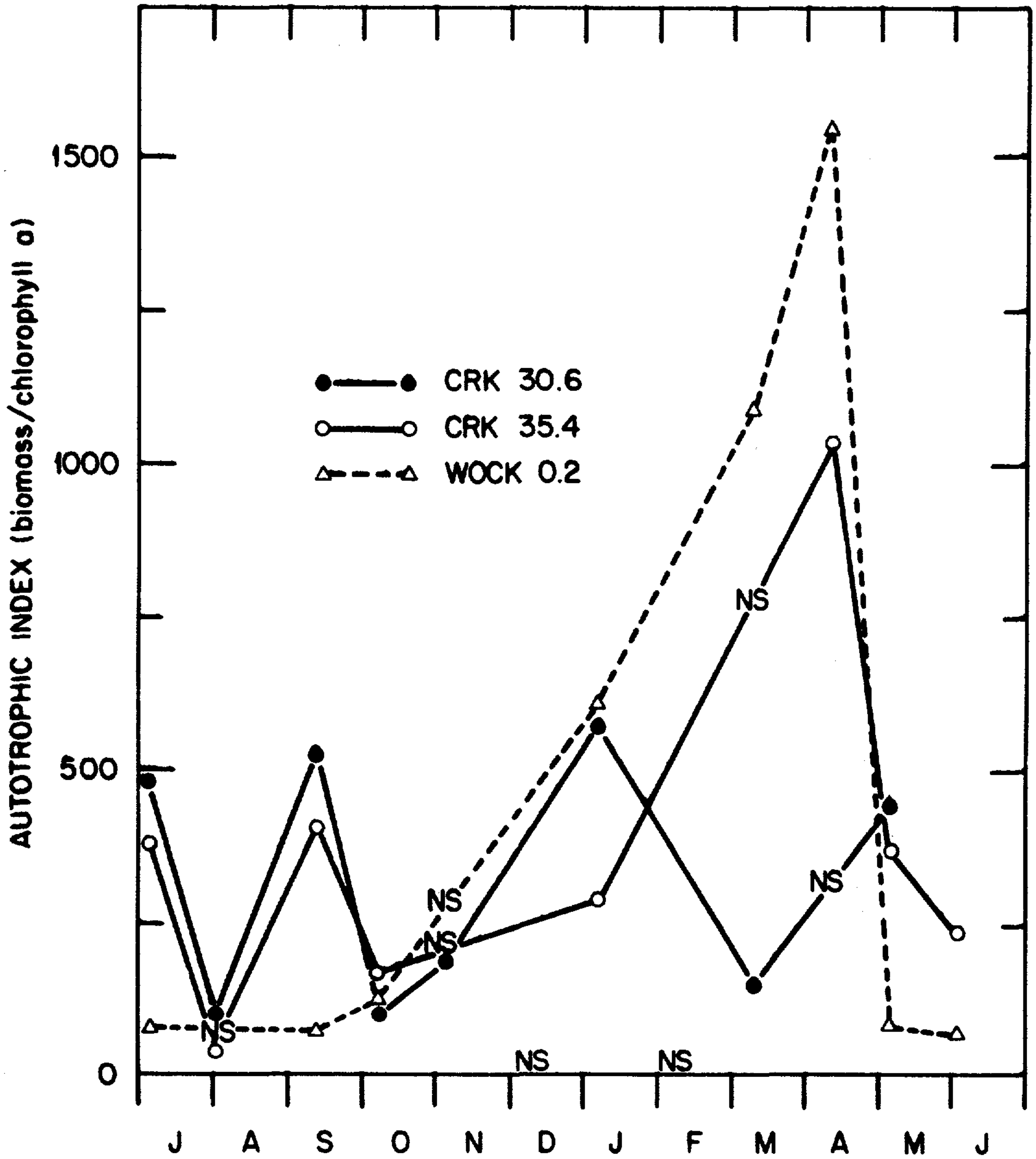

Fig. 4.35. Temporal fluctuations in the autotrophic index values (ratio of biomass to chlorophyll a) for periphyton on plexiglass slides in White Oak Creek embayment [station White Oak Creek kilometer (WOCK) 0.2] and the Clinch River above [Clinch River kilometer (CRK) 35.4] and below (CRK 30.6) the mouth of White Oak Creek at CRK 33.5, July 1979-June 1980. Dates shown on the graph represent the last day of the 28-d colonization period. NS = no samples.

Table 4.17. Mean densities (number of individuals per 0.1 m^2) of benthic macroinvertebrates collected at a site 200 m upstream from the confluence of White Oak Creek and the Clinch River in 1974-75

Densities were computed from data reported as the total number of individuals in four Ponar dredge (15 × 15 cm) samples.

Taxon	November 1974	February 1975
Bryozoa		
Pectinatella magnifica	1.1	
Diptera		
Chironomidae	16.1	3.2
Ephemeroptera		
Hexagenia sp.	7.5	12.9
Mollusca		
Corbicula manilensis	2.2	1.1
Oligochaeta		
Tubificidae	2.2	

Source: B. G. Blaylock, unpublished data.

Taxonomic composition

Three major taxonomic groups, representing three phyla, made up the majority of the benthic macroinvertebrates collected in the White Oak Creek embayment and the Clinch River above and below the mouth of White Oak Creek (Table 4.18). Taken together, these groups accounted for 84% of all the organisms from WOCK 0.2 and 97% of those collected at each of the river sites. Chironomids (Insecta: Diptera) were the dominant group throughout much of the year at all sites. Numerical dominance by the Asiatic clam, *Corbicula manilensis* (Mollusca: Pelecypoda) and oligochaetes (Annelida: Oligochaeta) occurred infrequently, and their dominance showed no consistent temporal pattern among the sites. Results obtained from previous surveys conducted below station CRK 30.6 also indicated that the benthic communities in the Clinch River are dominated by these three groups (Project Management Corporation 1975, Table 2.7-73; Exxon Nuclear Company, Inc., 1976, Table 2.7.11 and Sect. 2.7.1.1; Loar, in press, Table 1.6.4-6). In all of these studies, however, the relative abundance of oligochaetes exceeded that of chironomids.

Of the seven representatives of the phylum Mollusca that were collected from the Clinch River and White Oak Creek embayment (Appendix B-5), the most abundant was an introduced species, *Corbicula manilensis*. This species was not reported in an extensive survey (total of 306 sampling sites) of the mollusk fauna on and near the DOE Oak Ridge Reservation in 1961 (H. W. Van der Schalie and J. Burch, University of Michigan, unpublished data). The other taxa identified from the 1979-80 ORNL survey were represented by only one or two individuals, and none are listed as threatened or endangered by the State of Tennessee (Tennessee Wildlife Resources Commission 1975) or the U.S. Department of the Interior (1980). Several endangered species inhabit the Clinch River system (U.S. Department of the Interior 1980; Stansbery 1973), but none were identified in recent surveys of the lower Clinch River. (Project Management Corporation 1975, Table 2.7-71; Exxon Nuclear Co., Inc., 1976, Table 2.7-10;* Loar, in press, Appendix B-3).

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*The species list in Table 2.7-10 includes a taxon identified as "cf. *Fusconaia* sp." Two species belonging to this genus (*F. cuneolus* and *F. edgariana*) are on the state and federal endangered species lists.

Table 4.18. Relative abundance (%) of the three major taxonomic groups of benthic macroinvertebrates collected at three sites during the ORNL biological survey, March 1979–February 1980

	March/ April	June	July	August	September	October	December	February	Total
WOCK[a] 0.2									
Chironomidae	42.3	47.1	68.0	31.7	50.0	14.3	61.5	25.0	42.5
Corbicula manilensis	15.4	47.1	12.0	29.3	25.0	78.6	1.9	42.3	31.4
Oligochaeta	11.5	0.0	8.0	39.0	16.7	0.0	0.0	9.6	10.6
CRK[b] 30.6									
Chironomidae	58.8	31.6	53.2	38.0	48.8	60.4	74.1	90.2	56.9
Corbicula manilensis	8.8	31.6	1.8	36.6	16.3	8.6	7.4	1.6	14.1
Oligochaeta	23.5	31.6	45.0	19.7	33.7	29.4	18.5	8.2	26.2
CRK 35.4									
Chironomidae	28.8	40.9	57.6	34.5	67.2	46.1	52.9	77.8	50.7
Corbicula manilensis	44.2	45.4	27.3	56.0	2.0	6.7	3.9	11.1	24.6
Oligochaeta	25.0	9.1	12.1	9.5	28.7	47.2	41.2	0.0	21.6

[a] White Oak Creek kilometer.

[b] Clinch River kilometer.

Temporal patterns in density

Benthic macroinvertebrate densities in the Clinch River exhibited a seasonal pattern with peak densities occurring in early fall (Fig. 4.36). Densities at station WOCK 0.2, however, exhibited no well-defined seasonal patterns; densities in the winter were slightly higher than the small peak that occurred in August. Unlike the patterns exhibited by the Clinch River benthic community, densities in White Oak Creek embayment remained consistently low throughout the sampling period, and from August through October they were considerably lower than the densities found in the river.

The occurrence of these fall peaks at the two river sites was due to a sharp increase in the abundance of chironomids (Fig. 4.37). Although the density of oligochaetes also increased during the fall, their contribution to the peak in total density was much smaller (Table 4.18). During September and October, numerous chironomid pupae were observed in the samples from both stations, suggesting that the decline in late fall was due to emergence. The gradual increase in density prior to September was due to growth, maturation, and, consequently, recruitment to the sampling gear (actually to the screens used to sieve the samples). The smaller peak that occurred in July at station CRK 30.6 was most likely the result of sampling variability. For example, the density of chironomids and oligochaetes in one sample was 194 and 164 organisms/0.1 m^2, respectively, whereas the mean density in the other four samples from the transect was only 15 and 13 organisms/0.1 m^2.

The occurrence of peak densities of *Corbicula manilensis* in August (Fig. 4.18) was the result of spawning which occurs from July through November in Tennessee (Sinclair and Isom 1963). Based on size frequency distributions of clams collected on artificial substrates, spawning in the Clinch River in 1974 was postulated to have occurred throughout the summer but was greatest during August and September (Project Management Corporation 1975, Sect. 2.7.2.4.5). During the 1977-78 ORGDP benthic survey (Loar, in press), peak densities of *C. manilensis* in the vicinity of Poplar Creek and the Clinch River occurred in September. In both the ORGDP and ORNL surveys, very low densities were found during the winter.

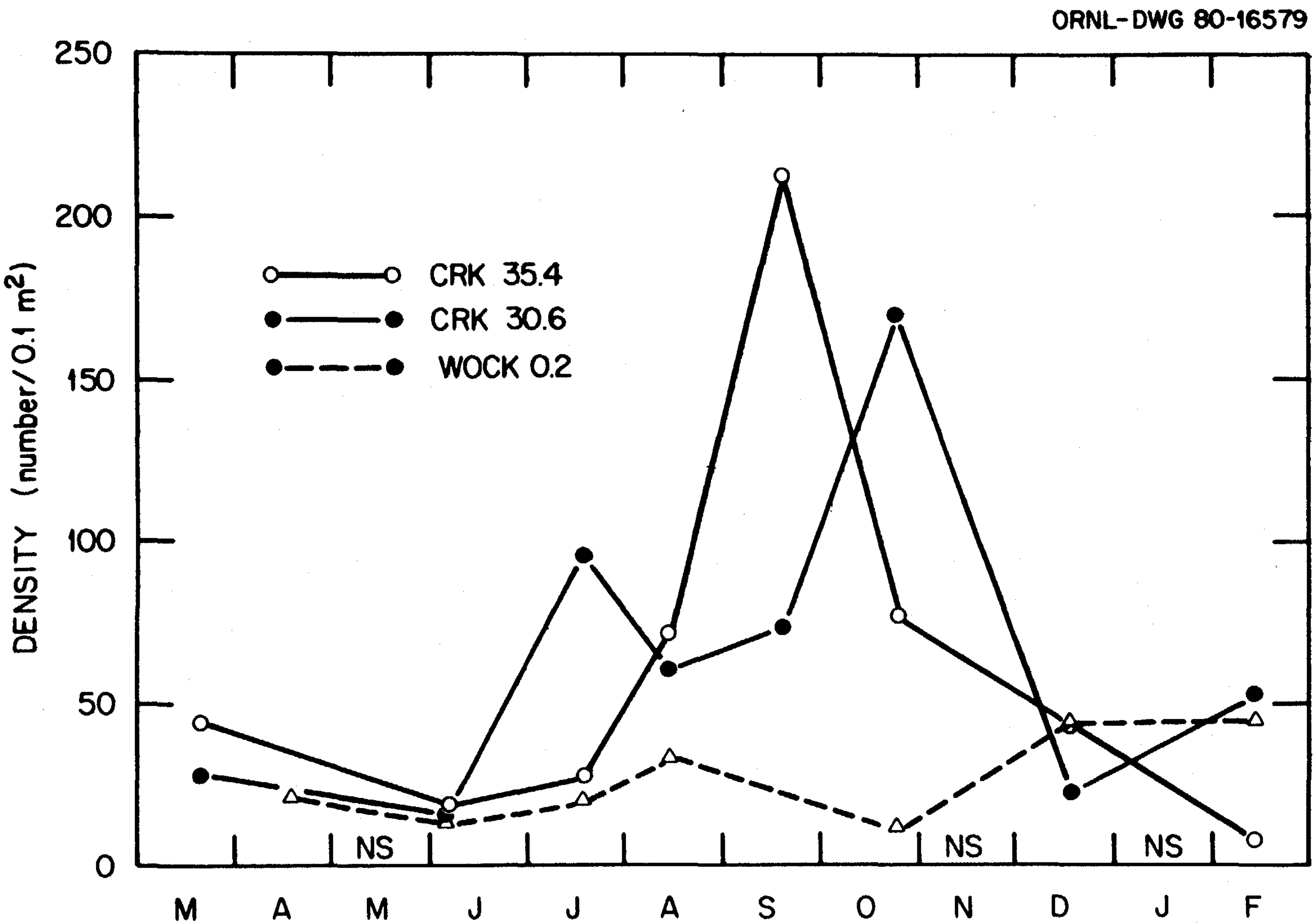


Fig. 4.36. Temporal fluctuations in total benthic macroinvertebrate densities (all taxa combined) at stations on lower White Oak Creek and the Clinch River, March 1979-February 1980. The confluence of White Oak Creek and the Clinch River is located at Clinch River kilometer (CRK) 33.5. NS = no samples taken. WOCK = White Oak Creek kilometer.

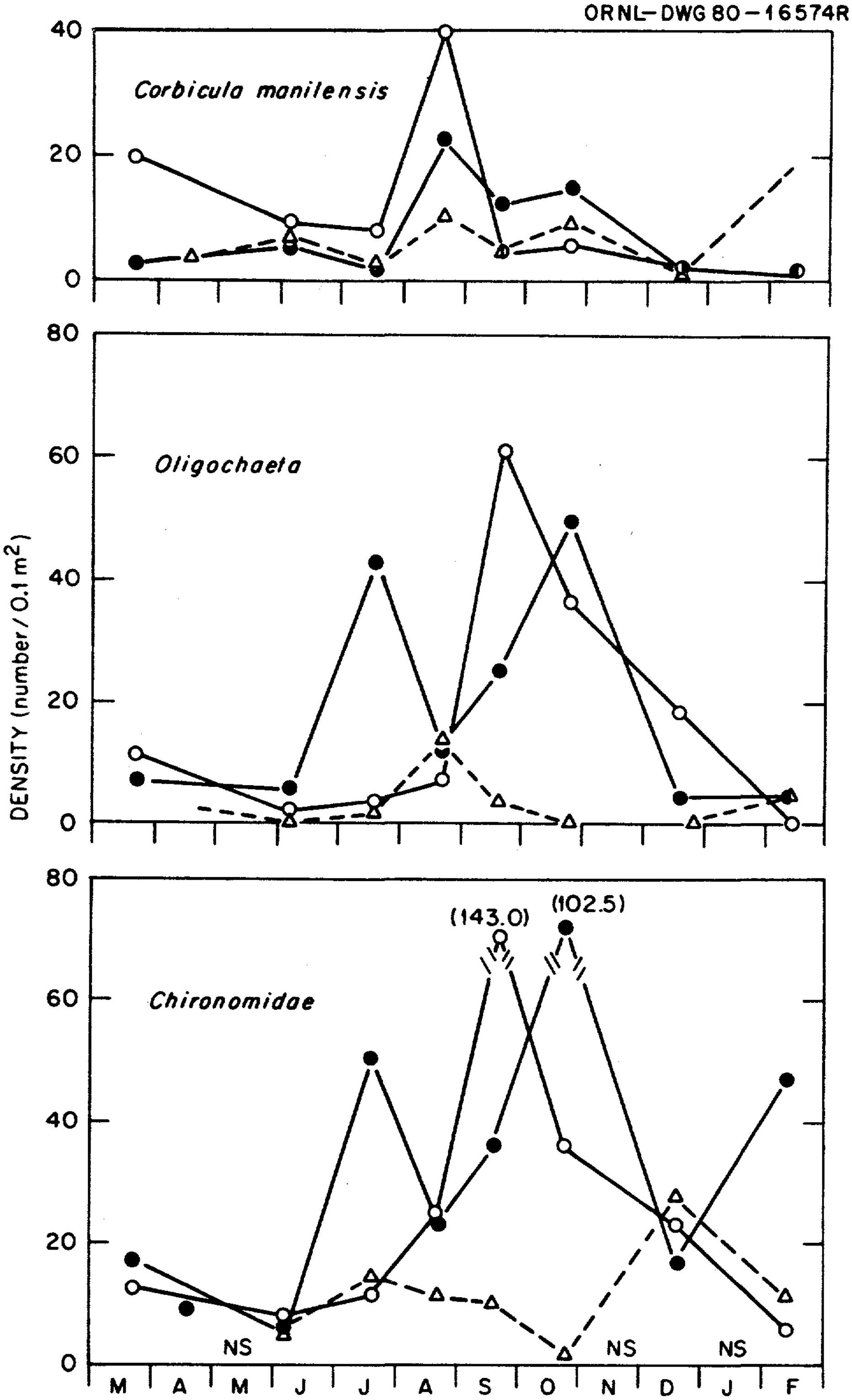


Fig. 4.37. Temporal fluctuations in the density of the three major groups of benthic macroinvertebrates found at stations White Oak Creek kilometer (WOCK) 0.2 (Δ----Δ) Clinch River kilometer (CRK) 30.6 (●——●), and CRK 35.4 (o——o), March 1979-February 1980. NS = no samples taken.

High winter mortalities of *C. manilensis* in the Ohio River have been attributed to increased suspended sediment loading in February and March (Bickel 1966), but loss to predators could also be significant.

Spatial distribution

As pointed out previously, the relative abundance of oligochaetes exceeded that of chironomids in earlier studies conducted between CRK 28.8 and 16.9, whereas just the opposite was found in samples collected near Melton Hill Dam during the present study. These differences in the spatial distribution of oligochaetes and chironomids may be related to differences in substrate between the two sampling areas. Densities of oligochaetes have been shown to be highest in areas of the Clinch River where the sediment consists primarily of fine sand (0.075 to 0.25 mm), whereas chironomids were distributed over a wide range of sediments, from fine sand to gravel (1.7 to >5.6 mm) (Project Management Corporation 1975, Table 2.7-78). In the ORNL survey, sampling sites (transects) were located in a region of the river below Melton Hill Dam where areas of significant sediment deposition are limited due to high current velocities. Deposition generally increases farther downstream and extends laterally over a wider portion of the river bed (Clinch River Study Steering Committee 1967). Thus, the greater abundance of oligochaetes relative to that of chironomids below CRK 30.6 probably reflects this change in sediment composition. Likewise, the abundance of *Hexagenia* sp., a burrowing mayfly usually found associated with fine sediments (silt/clay), was relatively high in previous studies conducted in the vicinity of Poplar Creek (CRK 16.9 to 24.1) (Exxon Nuclear Company, Inc., 1976; Loar, in press). In the present study, however, only a single individual was collected (station CRK 30.6 in March).

The relatively coarse substrate that exists near the mouth of White Oak Creek (station WOCK 0.2) can also explain the low relative abundance of oligochaetes. Although the relative abundance of major taxa was similar to that found at the two Clinch River sites (Table 4.18), several taxa found in White Oak Lake were also found at this site. For example, *Caenis* was collected in December and February (relative abundance of 21% and 17%, respectively) and *Palpomyia* and an unidentified Heleidae were also found but were rare, comprising only 1 and 2%, respectively, of the organisms collected at this site. Although *Hexagenia* was abundant in the limited samples taken in 1974-75 (Table 4.17), no individuals were found in more extensive sampling conducted in the same area in 1979-80. The earlier study characterized the substrate as fine gravel/coarse sand (which adequately describes the substrate encountered during this study), an environment that would not be associated with high *Hexagenia* densities. It is possible that mayflies identified as *Hexagenia* in the earlier study were in fact *Caenis*. The latter genus was abundant in White Oak Lake, and 80% of the individuals were collected from the old creek channel near the east shore where the substrate consists primarily of small rubble and gravel.

The differences in the taxonomic composition of the benthic communities between the White Oak Creek embayment and Clinch River sites were not great enough to significantly affect the Bray-Curtis dissimilarity values of these communities (Table 4.19). Although the similarity between the embayment and river sites was less than that between the two river sites, the difference was not statistically significant ($p > 0.05$). Since three major groups (Chironomidae, Oligochaeta, and Pelecypoda) accounted for the majority of the benthic macroinvertebrates at the three sites, these groups were included in a univariate analysis of variance. The densities of chironomids and oligochaetes at station WOCK 0.2 were significantly lower ($p < 0.01$) than the densities at either of the two river stations (Table 4.20). Differences in hydrology between White Oak Creek embayment and the Clinch River may account, in part, for the differences in benthic macroinvertebrate densities (Sects. 2.3 and 2.4). Erosion caused by fluctuating water levels and, at times, high current velocities of varying direction may alter the substrates in the embayment. Although silt/clay substrates exist near station WOCK 0.2, coarser substrates (with lower densities of chironomids and oligochaetes) may be more common. This hypothesis also accounts for the absence of any significant differences in the densities of Pelecypoda among the three sites ($p > 0.05$). The dominant pelecypod at all sites was the Asiatic clam, *Corbicula manilensis* (Pelecypoda: Corbiculidae), which has been

Table 4.19. Comparison of the mean coefficients of dissimilarity (± 1 standard error) for the benthic macroinvertebrate communities between all combinations of stations White Oak Creek kilometer (WOCK) 0.2, Clinch River kilometer (CRK) 35.4, and CRK 30.6

Tabular values were derived from coefficients computed separately for each sampling date, March 1979–February 1980. Means that do not have the same letter in their superscript are significantly different ($p < 0.05$)

	WOCK 0.2	CRK 35.4	CRK 30.6
WOCK 0.2		0.535[a] (0.062)	0.538[a] (0.062)
CRK 35.4			0.444[a] (0.051)
CRK 30.6			

Table 4.20. Comparison of the geometric mean densities of the three major groups of benthic macroinvertebrates among stations White Oak Creek kilometer (WOCK) 0.2, Clinch River kilometer (CRK) 35.4, and CRK 30.6

Values not connected by the same line are significantly different ($p < 0.01$)

	WOCK 0.2	CRK 35.4	CRK 30.6
Chironomidae	1.39	4.89	4.44
Oligochaeta	0.33	1.36	1.63
Pelecypoda	0.86	0.97	0.89

shown to have the highest densities in relatively coarse substrates (Project Management Corporation 1975, Table 2.7-72).

Results of the univariate analyses of variance indicated no significant difference in the abundance of chironomids, oligochaetes, or pelecypods between stations CRK 35.4 and 30.6 ($p > 0.05$). Consequently, a multivariate analysis of variance was performed using the abundance of the three groups as response variables and the collection date as a blocking factor. Again, no significant difference in benthic macroinvertebrate abundance between the two sites could be detected ($p > 0.80$).

4.3.6 Fishes

Previous survey

The fish community in the Clinch River was sampled on two occasions prior to completion of Melton Hill Dam at CRK 37.2. Rough species (those in the families Catostomidae, Clupeidae, Cyprinidae, Hiodontidae, Lepisosteidae, and Sciaenidae, as given in Table 4.3.6-1) made up more than 80% of the total fish collected by gillnetting at four sites above CRK 37.2 (Fitz 1968). These species also dominated the catch (57% of the total number collected) in hoop nets set at 16 sites between CRK 26.5 and 35.1 during a study of fish movements in the Clinch River (Morton 1962). Species composition was also similar in the two studies (Table 4.21), although nine species reported by Fitz (1968) were not found by Morton (1962). The differences in relative abundance and species composition between these preimpoundment surveys can probably be attributed to the use of different sampling procedures (i.e., gear type, sampling periods, and locations).

The only postimpoundment fisheries survey in the immediate study area was conducted between July 1974 and February 1975 (B. G. Blaylock, unpublished data). In this study, the fish community in White Oak Creek embayment was sampled by electroshocking (Table 4.22). Clupeids were the most abundant group, and gizzard shad were collected in seven of the eight months during which sampling was done. Threadfin shad abundance was very high only in February, suggesting that this species, which is

Table 4.21. Results of two fishery surveys conducted in the Clinch River prior to operation of Melton Hill Dam

Results from Morton (1962) are expressed as the number of fish tagged, but, except for gizzard shad, all fish captured were tagged routinely. An "X" denotes the presence of the species in at least one of the gill net samples

Species	Morton (1962)[a]	Fitz (1968)[b]
Catostomidae		
River carpsucker (*Carpiodes carpio*)	183	X
Quillback (*C. cyprinus*)	11	X
Smallmouth buffalo (*Ictiobus bubalus*)	639	X
Bigmouth buffalo (*I. cyprinellus*)	1	X
Black buffalo (*I. niger*)	6	X
River redhorse (*Moxostoma carinatum*)	2	X
Black redhorse (*M. duquesnei*)	1	X
Golden redhorse (*M. erythrurum*)	94	X
Total	937	
Centrarchidae		
Rock bass (*Ambloplites rupestris*)	6	X
Bluegill (*Lepomis macrochirus*)	149	X
Longear sunfish (*L. megalotis*)	2	
Smallmouth bass (*Micropterus dolomieui*)	2	*c*
Spotted bass (*M. punctulatus*)	2	X
Largemouth bass (*M. salmoides*)	5	
White crappie (*Pomoxis annularis*)	1027	X
Black crappie (*P. nigromaculatus*)	9	
Total	1193	
Clupeidae		
Skipjack herring (*Alosa chyrsochloris*)	30	X
Gizzard shad (*Dorosoma cepedianum*)	577	X
Cyprinidae		
Carp (*Cyprinus carpio*)	978	X
Hiodontidae		
Mooneye (*Hiodon tergisus*)	12	X
Ictaluridae		
Blue catfish (*Ictalurus furcatus*)	24	
Yellow bullhead (*I. natalis*)	2	
Channel catfish (*I. punctatus*)	151	X

Table 4.21 (continued)

Species	Morton (1962)[a]	Fitz (1968)[b]
Ictaluridae (continued)		
Flathead catfish (*Pylodictis olivaris*)	10	
Total	187	
Lepisosteidae		
Longnose gar (*Lepisosteus osseus*)	3	X
Percichthyidae		
White bass (*Morone chrysops*)	812	X
Percidae		
Walleye (*Stizostedion v. vitreum*)	1	
Sauger (*S. canadense*)	42	X
Sciaenidae		
Freshwater drum (*Aplodinotus grunniens*)	463	X
Total	5244	

[a]Hoop nets with 2.5-cm (1-in.) mesh were set close to shore at 16 sites between Clinch River kilometer (CRK) 26.6 and CRK 35.1 (Morton 1961). The mouth of White Oak Creek is located at CRK 35.5. Sampling was conducted from July 6 through September 21, 1960, and from April 12 through July 13, 1961 (Morton 1962).

[b]Four to six gill nets of 2.5- to 7.6-cm (1- to 3-in.) bar mesh were set for about 24 h at four stations above CRK 37.2. The nets were set 18 times in various seasons between November 1960 and June 1962.

[c]Collected in preimpoundment cove rotenone sample.

Table 4.22. Comparison of the species composition and abundance of fishes collected by electroshocking near the mouth of White Oak Creek from July 1974-February 1975 and June-December 1979

A 150-m section of the creek about 200 m above the mouth was sampled in the 1974-75 survey using the same equipment as that used in 1979 (Sect. 3.1)

	1974-75[a]								Total	1979-80							Total
	J	A	S	O	N	D	J	F		J	J	A	S	O	N[b]	D	
Catostomidae																	
Black buffalo			5						5								
Smallmouth buffalo			1					1	2								
Silver redhorse[c]		1				3			4		2	1					3
Centrarchidae																	
Bluegill			5	1	7			7	20	1	3		5				9
Largemouth bass			1		1				2								
White crappie					1			1	2								
Clupeidae																	
Gizzard shad	2		4	11	5	1	8	9	40	6	4	3	2	16		1	32
Skipjack herring						1			1								
Threadfin shad					2			100	102								
Cyprinidae																	
Carp			4		1			1	6	2							2
Emerald shiner[d]		7							7	4	4	2					10
Ictaluridae																	
Channel catfish													1				1
Percichthyidae																	
Yellow bass										9							9

Table 4.22 (continued)

	1974-75[a]								Total	1979-80							Total
	J	A	S	O	N	D	J	F		J	J	A	S	O	N[b]	D	
Percidae																	
Sauger			1						1					1			1
Yellow perch													1				1
Sciaenidae																	
Freshwater drum			1			1			2								
Total	2	8	22	12	17	6	8	119		22	13	6	9	17		1	

[a]Source: B. G. Blaylock, unpublished data.

[b]No sample taken.

[c]Identified as "redhorse" in the 1974-75 survey.

[d]Identified as "shiners" in the 1974-75 survey.

stressed by low temperatures (Griffith 1978), may move into the warmer waters found near the mouths of creeks in late winter. A similar phenomenon occurred at the same time near the mouth of Paw Paw Creek, a tributary of the Clinch River located near CRK 19.5 (B. G. Blaylock, unpublished data). With the exception of the yellow bass, which may be recent inhabitants of this region of the river, the species composition and abundance of fishes observed during the 1974-75 survey was similar to that found in 1979 (Table 4.22). In the 1979-80 sampling program, no species were collected that are listed as threatened or endangered by the State of Tennessee (U.S. Wildlife Resources Commission 1975) or the U.S. Department of the Interior (1980).

No recent fishery surveys have been made of the Clinch River just below Melton Hill Dam. However, extensive sampling was conducted from CRK 28.8 downstream to CRK 16.9 between 1973 and 1978. The results of these surveys and the changes that have occurred since completion of the Melton Hill Dam in 1963 were reviewed previously (see Loar, in press).

Species composition and relative abundance

One of the most widely distributed and more abundant species in the lower Clinch River is the gizzard shad. It was the dominant species in the community at WOCK 0.2 in both the 1974-75 and 1979-80 surveys (Table 4.22) and was also abundant at stations CRK 35.4 and 30.6 (Table 4.23). One of the major spawning areas of the gizzard shad is Poplar Creek (Loar, in press), located about 14 km downstream from White Oak Creek. Although large numbers of ripe adults were collected there in the spring of 1977, no such migration into White Oak Creek was observed in 1979. There is no way to determine whether the clupeid larvae collected at station WOCK 0.2 (Sect. 4.3.4) were hatched from eggs actually deposited in the creek or transported to this area from the Clinch River and/or White Oak Lake.

Although the relative abundance of clupeids (mostly gizzard shad) was similar at all three sampling sites (Fig. 4.38), the community at station WOCK 0.2 was characterized by having a higher relative abundance of cyprinids and a lower abundance of percids than the two river sites.

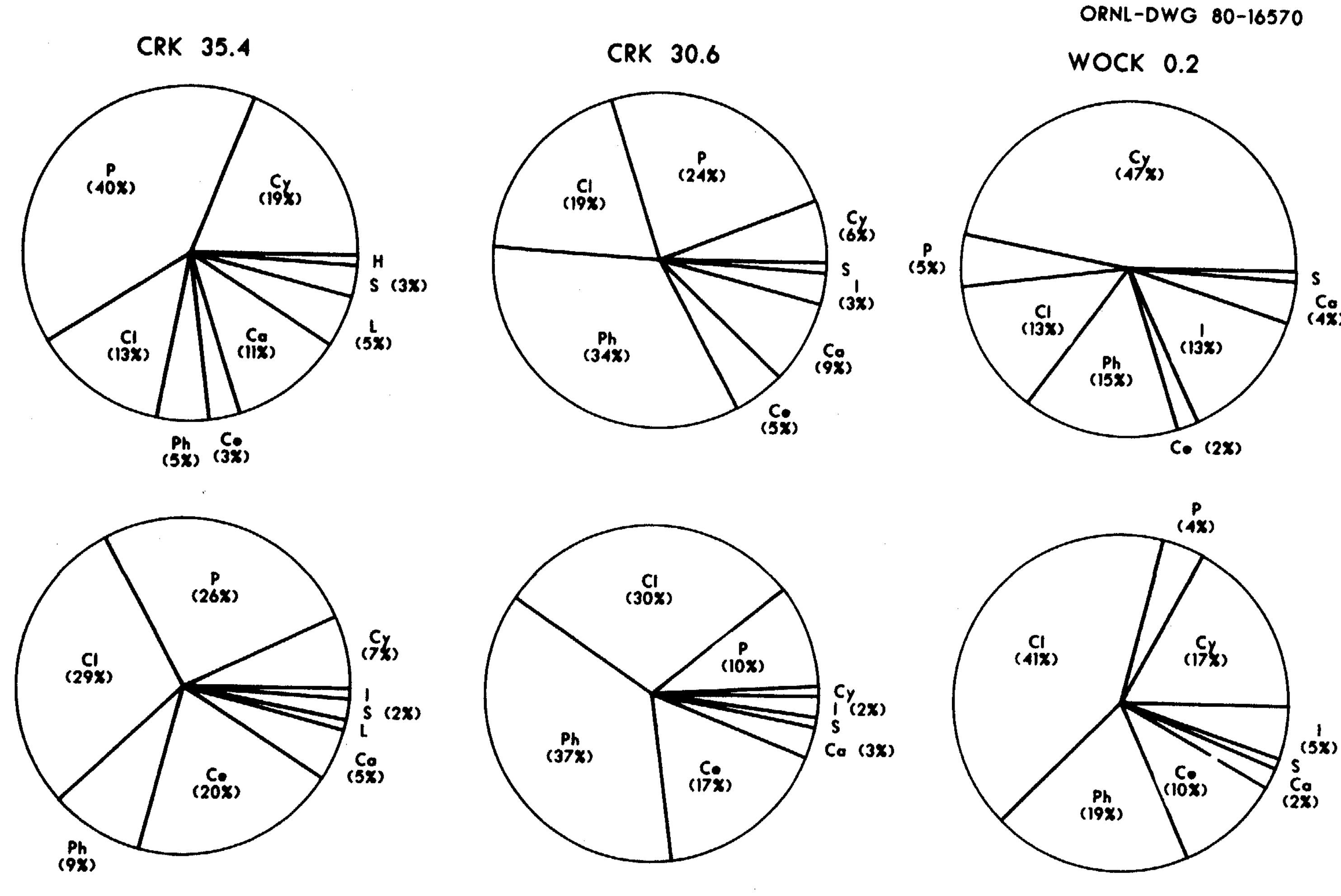
Table 4.23. Total number of fish collected by gillnetting (G) and electroshocking (E) at stations Clinch River kilometer (CRK) 35.4, 30.6, and White Oak Creek kilometer (WOCK) 0.2

Tabular values are based on nine gill net samples and six electroshocking samples collected at each site from March 1979-February 1980

Family	CRK 35.4		CRK 30.6		WOCK 0.2	
	G	E	G	E	G	E
Catostomidae						
Northern hog sucker	1					
Quillback carpsucker	4		2			
Silver redhorse	1	1		2		3
Total	6	1	2	2		3
Centrarchidae						
Bluegill	3	17	4	11	1	9
Redbreast sunfish				1		
Redear sunfish		1				
Rock bass			2			
White crappie	1	7	1	3	2	
Total	4	25	7	15	3	9
Clupeidae						
Gizzard shad	13	20	5	27	13	32
Skipjack herring	8		3		1	
Threadfin shad	3		3		1	
Total	24	20	11	27	15	32
Cyprinidae						
Carp	1	7		1	7	2
Emerald shiner		1				10
Goldfish		1				
Total	1	9		1	7	12
Hiodontidae						
Mooneye	1					
Ictaluridae						
Channel catfish			1		5	1
Lepisosteidae						
Longnose gar	1					

Table 4.23 (Continued)

Family	CRK 35.4		CRK 30.6		WOCK 0.2	
	G	E	G	E	G	E
Percichthyidae						
Striped bass			4		3	
White bass	4		3		1	
Yellow bass	9		33	6	9	9
Total	13		40	6	13	9
Percidae						
Sauger	38	1	13		3	1
Yellow perch						1
Total	38	1	13		3	2
Sciaenidae						
Freshwater drum		3		1	1	
Total fish collected	88	59	74	52	47	68



KEY: Ca = *Catostomidae*
Ce = *Centrarchidae*
Cl = *Clupeidae*
Cy = *Cyprinidae*
H = *Hiodontidae*
I = *Ictaluridae*
L = *Lepisostidae*
Ph = *Percichthyidae*
P = *Percidae*
S = *Scianidae*

Fig. 4.38. Relative abundance (%) of fishes, by family, based on weight (top) and numbers (bottom) at stations Clinch River kilometer (CRK) 35.4, 30.6, and White Oak Creek kilometer (WOCK) 0.2, March 1979–February 1980. Samples obtained by gill netting and electroshocking were combined in the computation of relative abundance. Where no percentage is given for a particular family, the relative abundance was ≤1%.

The dominance of Cyprinidae (on the basis of biomass) at station WOCK 0.2 was due to the presence of several large carp collected in late spring (mean total length = 56.2 cm; mean weight = 2704 g; n = 4). Channel catfish were also more abundant at this site than the Clinch River, and these two families (Cyprinidae and Ictaluridae) accounted for 60% of the fish biomass in lower White Oak Creek. Although no carp larvae were collected in this region of the creek, spawning activity was observed on June 8, 1979, during routine ichthyoplankton sampling.

Although few percids were found in White Oak Creek, they were the dominant group, on a biomass basis, at station CRK 35.4 (Fig. 4.38). A single species, sauger, dominated the gill net catch in mid-March (Fig. 4.39). The movement of sauger into the Clinch River tailwaters in late winter supports a popular sport fishery, not only below Melton Hill Dam, but below several mainstream reservoirs as well (e.g., Fort Loudoun and Watts Bar). Sport fishery for the striped bass that have been stocked in Watts Bar Reservoir is increasing (C. C. Coutant, personal communication). This species also migrates upstream to the tailwaters below Melton Hill Dam in spring, and several individuals were caught at station CRK 30.6 (Fig. 4.39). Occasional catches were also made in White Oak Creek embayment.

A third species, the white bass, is also a popular sport species in the lower Clinch River at this same time of year. The major spawning area, however, is located in Poplar Creek above ORGDP (i.e., above kilometer point 8.0). Relatively few individuals were collected in the Clinch River just below Melton Hill Dam in 1979 (Fig. 4.39).

The yellow bass belongs to the same genus (*Morone*) as both the striped bass and white bass and was particularly abundant at station CRK 30.6 (Table 4.23). Its presence accounted for the high relative abundance of the family Percichthyidae at this site. The dominance of this family, on the basis of weight, however, was primarily due to the presence of a few, but large, striped bass (see Appendix D-1). The distribution and abundance of yellow bass in the Clinch River has apparently increased over the past several years. The species was not found in the surveys conducted prior to 1975 but was found in low abundance (<0.6% of the

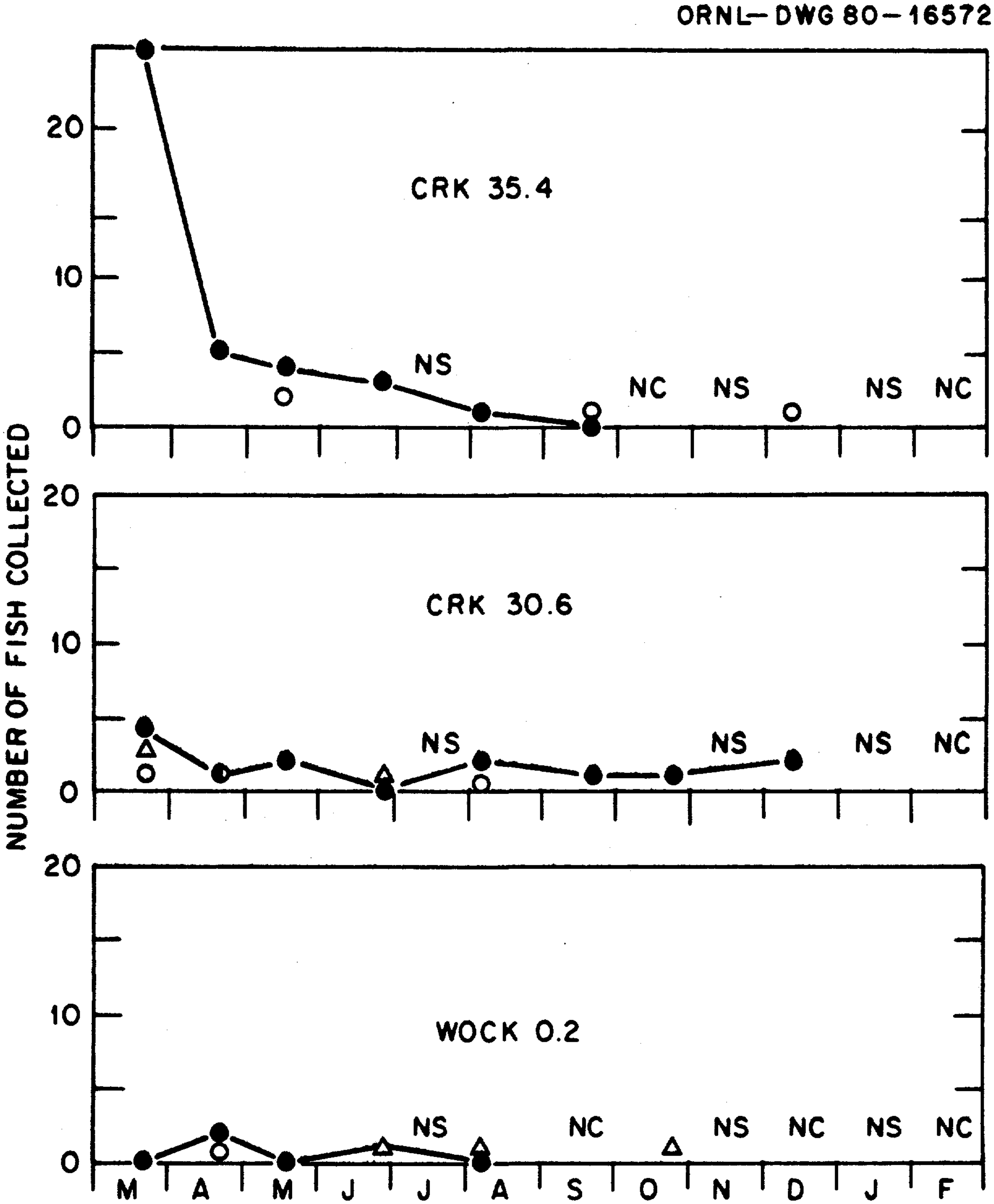


Fig. 4.39. Seasonal distribution of sauger (●——●), white bass (o), and striped bass (Δ) in gill net samples taken at stations Clinch River kilometer (CRK) 35.4, 30.6, and White Oak Creek kilometer (WOCK) 0.2, March 1979-February 1980. NC = no fish collected; NS = no samples taken.

total catch) during a 1975-76 survey conducted at four sites between the mouth of Poplar Creek (CRK 19.3) and CRK 24.1 (Exxon Nuclear Company, Inc., 1976, Table 2.7-15). The species constituted 20% of the catch at station CRK 24.1 during the 1977-78 ORGDP survey (Loar, in press, Table 1.6.5-6). That the species is not migratory like other *Morone* species is indicated by the presence of individuals in samples taken throughout most of the year.

Additional information on the fishes of the lower Clinch River is available from several sources. Spawning behavior, food habits, and general life history information are summarized in the Environmental Report for the Exxon Nuclear Fuel Recovery and Recycling Center (Exxon Nuclear Company, Inc., pp. 2.7-18 to 2.7-25 and Appendix 2B). Analysis of the food habits of several species was conducted during the aquatic preoperational survey for the Clinch River Breeder Reactor Project (Project Management Corporation 1975, Sect. 2.7.2.4.9).

4.4 TRACE ELEMENTS IN FISH

The presence of trace elements, particularly heavy metals, in aquatic systems can result in their uptake and potential accumulation by biota. The distribution and bioaccumulation of mercury has been intensively studied, in part because of the potential threat to humans from the consumption of contaminated biota. Although other heavy metals are also toxic (depending upon their concentration in water, in dissolved vs particulate fractions, and the duration of exposure), their bioaccumulation potential has not been as extensively investigated.

The present study examined the concentrations of seven heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, and Zn) in selected fish species in the vicinity of ORNL. The study had two major objectives: (1) to examine the levels of these seven elements in migratory species that compose an important sport fishery in the Clinch River below Melton Hill Dam and (2) to compare the levels of these elements in resident fishes from lower White Oak Creek watershed with those from the Clinch River and from Melton Hill Reservoir, an uncontaminated control site. Migratory species included sauger and striped bass. White bass were not included, since extensive studies of heavy metal contamination of this species had been conducted previously in the vicinity of Poplar Creek (Loar, in press). For comparisons between stations, heavy metal concentrations were measured in bluegill, the most abundant resident species found at all the sampling sites. The results of these two studies are discussed separately in the following sections.

Migratory species

Sauger and striped bass enter the tailwaters below Melton Hill Dam in late winter and spring, respectively, and return to Watts Bar Reservoir in early summer. Sauger were collected in March 1979 from two sites in the Clinch River above and below the mouth of White Oak Creek. The mean axial muscle concentrations of six trace elements were not significantly different ($p > 0.05$) at the two sites (Table 4.24). Sauger are probably widely distributed throughout the tailwater region and not restricted to particular areas. Thus, the concentrations found in individuals from either site could reflect widely varying periods of exposure to different concentrations in the environment. The levels of the seven elements reported for sauger are similar to the levels found in other predatory species from uncontaminated areas (e.g., Uthe and Bligh 1971; Lovett et al. 1972; Wiener and Giesy 1979). However, four sauger collected from the Clinch River below Poplar Creek in the fall of 1977 had a mean total mercury concentration in muscle tissue of 0.48 μg/g, wet weight (range = 0.29 to 0.72 μg/g wet weight). Although the exposure history of these fish is unknown, it is possible that they could have spent extended periods of time in or near Poplar Creek where elevated mercury levels have been found in the sediments and other fish species (Loar, in press).

Several studies have shown a correlation between element concentration and size (either length or weight), although the nature of the relationship (i.e., either an increase or decrease in concentration with increasing size) described by various investigators has not always been consistent. One exception is mercury, which has been shown in several studies to be positively related to size (see review by Huckabee, Elwood,

Table 4.24. Comparison of the mean concentration (±1 S.E.) of seven trace elements in axial muscle of sauger collected in March 1979 at two sites in the Clinch River above and below the mouth of White Oak Creek [Clinch River kilometer (CRK) 33.5]

No significant differences in mean concentrations of six elements were found between the two sites ($p > 0.05$)

Site	Weight (g)		Mean concentration, µg/g wet wt						
	Mean	Range	Cd[a,b]	Cr	Cu	Hg[a]	Ni	Pb	Zn
CRK 35.4 (n = 10)[c]	576 (92)	150-1058	0.8 (0.1)	0.069 (0.026)	0.18 (0.01)	103 (15)	0.49 (0.08)	0.012 (0.001)	2.6 (0.2)
CRK 30.6 (n = 4)[c]	488 (108)	245-764	1.4 (1.0)	0.011 (0.001)	0.16 (0.02)	77 (17)	0.65 (0.19)	0.012 (0.002)	3.0 (0.1)

[a] Concentration in ng/g wet weight.

[b] "Less than" values were ignored in the computation of mean concentration; n = 3 (CRK 35.4) and n = 2 (CRK 30.6). No statistical analysis was performed.

[c] Number of samples analyzed for each element except Cd (see footnote *b*).

and Hildebrand 1979). The relationship between muscle concentration and body weight in sauger was examined by pooling the data from the two sampling sites. A significant relationship ($p < 0.05$) was found for two of the six elements included in the analysis (Table 4.25). The correlation between total mercury and body weight was positive, while the relationship for zinc was negative. Wiener and Giesy (1979) suggested that zinc, an essential element, did not accumulate with age but was homeostatically regulated. The correlation between chromium and body weight, although not significant ($p > 0.10$), was in the same direction as that observed by Elwood, Beauchamp, and Allen (1980) for bluegill and goldfish in White Oak Lake. Finally, cadmium was excluded from the analysis because of the high proportion of values that were below the detection limit (Appendix D-1). Other studies have shown no correlation between cadmium concentrations and size (Lovett et al. 1972; Tong et al. 1974; Murphy et al. 1978; Wiener and Giesy 1979).

Because of the small sample size, data for two other species, striped bass and yellow bass, were not statistically analyzed. However, the mean concentrations found in the axial muscle of these species were similar to those reported for sauger (Table 4.26). In addition, the levels found in white bass collected in 1977 from Poplar Creek were similar to the mean concentrations reported for other migratory species collected in the present study (Loar, in press, Tables 1.5-2 to 1.5-4). In all these species, the levels of total mercury were below the Food and Drug Administration action level of 1.0 μg/g, wet weight (Appendix D-1; Loar, in press, Appendix A).

Resident species

Since the bluegill was the only relatively abundant species at all five sites, it was chosen for analysis. To control for age dependency in some elements, especially mercury, attempts were made to collect ten bluegill of approximately the same size at each station. Because of their low abundance in White Oak Creek embayment, only four relatively small fish were collected. The fact that they were smaller than those collected at the other sites may account for the significantly higher ($p < 0.05$) concentration of zinc found in these fish (Table 4.27). The

Table 4.25. Results of correlation analysis between body weight and the concentration of six trace elements in axial muscle of sauger collected from the Clinch River in March 1979

Fish collected at stations CRK 35.4 and 30.6 were combined in the analysis (Appendix D-1); n = 14

	Cr	Cu	Hg	Ni	Pb	Zn
Correlation coefficient (r)	-0.303	-0.097	0.544	-0.346	-0.136	-0.619
Significance level (P)[a]	0.30	0.74	0.04	0.22	0.64	0.02

[a]P = probability of observing a larger value of r, by chance, given that the true value of r is actually zero.

Table 4.26. Mean concentration (±1 standard error) of seven trace elements in axial muscle of striped bass and yellow bass collected at station Clinch River kilometer (CRK) 30.6 in March 1979

	Mean weight (g)	Mean concentration, μg/g wet wt[a]						
		Cd[a,b]	Cr	Cu	Hg[a]	Ni	Pb	Zn
Striped bass (n = 3)[c]	1250 (738)	0.5	0.017 (0.005)	0.24 (0.04)	134 (43)	1.54 (1.18)	0.009 (0.004)	3.0 (0.3)
Yellow bass (n = 3)[c]	98 (19)	1.4 (0.3)	0.020 (0.003)	0.34 (0.07)	100 (24)	1.28 (0.17)	0.027 (0.013)	4.1 (0.4)

[a] Concentration in ng/g wet weight.

[b] "Less than" values ignored in the computation of mean concentration; n = 1 (striped bass) and n = 3 (yellow bass).

[c] Number of samples analyzed for each element except Cd (see footnote *b*).

Table 4.27. Comparison of the mean concentration (±1 standard error) of seven trace elements in axial muscle of bluegill collected at five sites (approximate locations given in parentheses)

n = 10 for all sites except WOCK 0.2 (n = 4)

Site	Mean weight (g)	Mean concentration, μg/g wet wt						
		Cd[a]	Cr[b]	Cu	Hg[c]	Ni	Pb	Zn[d]
White Oak Lake (WOCK 1.1)	86.2 (4.8)	5.7 (1.8)	0.027 (0.003)	0.16 (0.01)	0.70 (0.07)	0.46 (0.14)	0.039 (0.006)	5.9 (0.2)
White Oak Creek embayment (WOCK 0.2)	48.0 (5.4)	3.9 (2.5)	0.042 (0.008)	0.31 (0.17)	0.57 (0.07)	0.22 (0.15)	0.040 (0.008)	10.1 (3.0)
Clinch River (CRK 30.6)	85.6 (8.4)	20.7 (6.6)	0.056 (0.012)	0.31 (0.10)	0.06 (0.01)	0.60 (0.16)	0.061 (0.026)	5.4 (0.5)
Clinch River (CRK 35.4)	77.2 (7.0)	9.7 (3.5)	0.038 (0.004)	0.19 (0.03)	0.21 (0.10)	0.88 (0.36)	0.044 (0.007)	5.8 (0.4)
Melton Hill Reservoir (CRK 84)	89.7 (7.5)	17.8 (5.0)	0.030 (0.002)	0.16 (0.02)	0.06 (<0.01)	0.40 (0.06)	0.027 (0.002)	5.4 (0.3)

[a] ng/g, wet wt. "Less than" values were ignored in the computation of mean concentration. In the order listed, n = 9, n = 2, n = 6, n = 8, n = 10, respectively. No statistical analysis performed.

[b] Mean concentration at CRK 30.6 was significantly different from that at sites WOCK 1.1 and CRK 84 ($p < 0.05$).

[c] ng/g, wet wt. Mean concentration at sites WOCK 1.1 and WOCK 0.2 was not significantly different ($p > 0.05$), but the concentration at both sites was significantly different from that at the other three stations ($p < 0.05$).

[d] Mean concentration at WOCK 0.2 was significantly different from that at the other four sites ($p < 0.05$).

significantly higher concentration of chromium in bluegill from the Clinch River below White Oak Creek compared to the levels in bluegill from White Oak Lake and Melton Hill Reservoir is difficult to explain. If fish are exposed to elevated levels of chromium from White Oak Creek and if there are no other anthropogenic inputs in this region of the Clinch River, then differences might be expected between this site (CRK 30.6) and CRK 35.4, located about 2 km above White Oak Creek. Bluegill, however, may not inhabit relatively small areas of the river for long periods of time, but, rather, may be distributed throughout a larger area than that defined by the various sampling sites. Extensive movements could have resulted in the exposure of individuals in the population to varying levels of chromium at different stages in their life history. In addition to bluegill, such an explanation may account for the higher chromium concentrations in the sauger from CRK 35.4 compared with those collected near CRK 30.6 (Table 4.24). Differences in exposure history may also explain the occurrence of high mercury levels in two bluegill from station CRK 35.4 (1.07 and 0.51 μg/g, wet weight). Elevated mercury levels ($\geq$0.50 μg/g) were also reported in 7 of 15 *Lepomis* collected near CRK 24.1, about 5 km above Poplar Creek, a known source of mercury (Loar, in press, Appendix A-4).

The most significant finding in the study of trace element concentrations in bluegill was the occurrence of significantly higher levels of total mercury in the fish from White Oak Lake and White Oak Creek embayment compared with those collected from the Clinch River or Melton Hill Reservoir (Table 4.27). The levels in bluegill from White Oak Lake were similar to those found in *Lepomis* collected from the mouth of Poplar Creek in November 1977 ($\bar{x}$ = 0.62 μg/g, wet weight; range = 0.29 to 1.10 μg/g, wet weight, n = 11). Most of the fish from the latter site, however, were smaller than those collected from the lake or the embayment sites.

High levels of mercury were also found in the axial muscle of largemouth bass from White Oak Lake (Table 4.28). Concentrations were similar to those in bluegill, but conclusions regarding trophic transfer (or food chain magnification) cannot be made on the basis of such a small sample

Table 4.28. Mean concentration (±1 standard error) of seven trace elements in axial muscle of largemouth bass collected from White Oak Lake

Collection date	Mean weight (g)	Mean concentration, μg/g wet weight						
		Cd[a]	Cr	Cu	Hg	Ni	Pb	Zn
June 20, 1979 (n = 3)[b]	168.7 (77.2)	8.5 (4.5)	0.020 (0.003)	0.21 (0.02)	0.71 (0.22)	1.3 (1.1)	0.015 (0.056)	6.7 (0.6)
July 26, 1979 (n = 2)[b]	144.1 (92.0)	[c]	0.037 (0.003)	0.26 (0.04)	0.42 (0.06)	0.9 (0.56)	0.034 (0.005)	5.6 (1.7)

[a]ng/g, wet weight. "Less than" values were ignored in the computation of mean concentration; for June sample, n = 2.

[b]Number of samples analyzed for each element except Cd (see footnotes *a* and *c*).

[c]Both fish had cadmium concentrations of <1 ng/g, wet weight.

size. The source of mercury to these populations was investigated during the 1979-80 water quality sampling program. Elevated levels of mercury (and the other elements as well) were found throughout the sampling period in White Oak Creek below ORNL.

5. SUMMARY AND CONCLUSIONS

The biological sampling program conducted from March 1979 to June 1980 provided information that was used to characterize the aquatic communities in White Oak Creek watershed in the vicinity of Oak Ridge National Laboratory (ORNL). These data were compared with the results of previous surveys to document, if possible, changes that might have occurred since the initial survey in 1950-53. In many cases, no comparisons between studies were possible because of differences in sampling methodologies and/or sampling frequency. Major conclusions drawn from these comparisons are listed below.

1. Phytoplankton populations in White Oak Lake were considerably higher during the present survey than they were during the studies conducted in 1950-53 and 1956. These differences cannot be attributed solely to the inadequacy of previous sampling techniques, although nannoplankton densities were probably greatly underestimated in the initial survey. Rather, the high densities may be indicative of a system that has been subjected to high nutrient inputs over a period of at least 35 years.
2. Plankton population growth in White Oak Lake, unlike that in natural systems, is not limited by nutrients or some trace element(s) (e.g., silica), but rather is limited by the high flushing rate of the lake. Storm events can cause dramatic declines of several orders of magnitude in population density.
3. Ten years after the initial survey, construction of Melton Hill Dam was completed, and its operation has undoubtedly influenced the biotic communities in the embayment below White Oak Dam. Communities found in this area are similar in composition and abundance to those in the Clinch River, although the influence of plankton population dynamics in White Oak Lake is still obvious. Algal blooms generally coincide with the blooms in the lake, but the densities during these periods are probably lower than those observed by Lackey (1957). The benthic macroinvertebrate communities in the embayment are also similar to those found in the Clinch River.

4. Benthic macroinvertebrate communities in upper White Oak Creek watershed were similar to those described in previous studies. A depauperate fauna, comprised primarily of Chironomidae, exists below ORNL. Above the plant, however, taxonomic diversity is high, and groups such as Ephemeroptera and Plecoptera are numerically dominant.
5. Between 1953 and 1974, a significant change occurred in the benthic communities in Melton Branch. The high diversity reported in the initial survey has decreased, and in many respects (e.g., high abundance of Chironomidae) the community now resembles that found in White Oak Creek. Representatives of other groups (Ephemeroptera and Odonata), however, are present in low numbers.
6. The fish community in White Oak Lake has undergone several changes in composition that actually began during the initial survey. Some of these changes coincided with significant alterations in lake level. However, two species in the lake, mosquitofish and bluegill, have always been relatively abundant. Losses during storm events (severe floods) may account for the extinction of some species and for fluctuations in the abundance of others.
7. The high densities of *Chaoborus* found in White Oak Lake during the 1950-53 survey ($\overline{X}$ = 182 individuals/0.1 m^2) were not observed in a 1974-75 study or in the present one. Maximum densities in the latter two surveys were 3.2 and 0.2 individuals/0.1 m^2 respectively. Adequate information is not available, however, to evaluate the possible cause(s) for this decline in abundance.

In addition to providing a basis for comparison with previous surveys, the present study has also resulted in new information on communities or areas that had not previously been sampled. Some of the more important findings are discussed below.

1. Periphyton abundance in White Oak Lake near the dam is low compared with the abundance in the shallow upper end of the lake and at several upstream sites below ORNL. Although the periphyton communities at these latter sites were dominated by diatoms, the

community in the lake had a significant Chlorophyta component. At the control station above ORNL, periphyton abundance was relatively low and did not exhibit the dramatic seasonal fluctuations observed at the creek stations below ORNL.

2. The high densities of larval clupeids and *Lepomis* in White Oak Lake, primarily during May and June, indicate that spawning in the lake is significant. However, very limited spawning occurs in the creek below ORNL. Adult fish populations in this area and in Melton Branch may be very small. The species found in abundance above ORNL were not encountered below the plant.
3. The Clinch River immediately below Melton Hill Dam is characterized by low densities of phytoplankton but relatively high periphyton populations. The distribution of benthic populations is undoubtedly affected by dam operation, but densities in this region of the river were generally similar to those found 2 to 10 km downstream. Ichthyoplankton densities are low, and clupeids make up the majority of the fish larvae in this region of the river. Significant increases in density occur below Poplar Creek, an important spawning site of gizzard shad and white bass.
4. Large numbers of sauger from Watts Bar Reservoir migrate up the Clinch River to Melton Hill Dam in late winter. This migration supports a popular sport fishery at this time of year. Trace element concentrations in the muscle tissue of this species were similar to those reported in predatory fishes from uncontaminated areas.
5. Elevated total mercury levels were found in the muscle tissue of bluegill taken from White Oak Lake and White Oak Creek embayment ($\overline{X}$ = 0.70 and 0.57 μg/g, wet weight respectively). These levels were significantly greater ($p < 0.05$) than the levels found in bluegill from the Clinch River and Melton Hill Reservoir. Two bluegill from White Oak Lake and one individual collected near Clinch River kilometer 35.4 ($n = 10$ at each station) had mercury concentrations that slightly exceeded the Food and Drug Administration action level of 1.0 μg/g wet weight.

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Appendix A

PERIPHYTON AND BENTHIC MACROINVERTEBRATE TAXA COLLECTED IN UPPER WHITE OAK CREEK WATERSHED DURING THE ORNL SAMPLING PROGRAM

Table A.1. Periphyton taxa collected at four sites in upper White Oak Creek watershed, June 1979–March 1980

An "X" denotes presence of the taxon in at least one of the samples from that site

Taxon	White Oak Creek			Melton Branch
	WOCK 6.3[a]	WOCK 2.7	WOCK 2.1	MBK 0.6[b]
Chlorophyta				
Chlorococcales				
Ankistrodesmus	X	X	X	X
Chlorella		X	X	
Coelastrum			X	
Crucigenia			X	X
Golenkinia		X		
Kirchneriella		X	X	
Oocystis		X	X	
Pediastrum			X	
Scenedesmus	X	X	X	X
Schroederia			X	X
Tetraedron			X	
Tetrastrum		X		
Volvocales				
Chlamydomonas	X	X	X	X
Chlorogonium				X
Others				
Cosmarium				X
Gloeocystis	X	X	X	X
Mougeotia	X		X	X
Oedogonium	X		X	X
Protococcus	X	X	X	X
Stigeoclonium	X	X	X	X
Unidentified Chlorophyta	X		X	X
Chrysophyta				
Bacillariophyceae				
Achnanthes	X	X	X	X
Cocconeis	X	X	X	X
Cyclotella		X	X	
Cymbella	X	X	X	X
Diatoma	X	X	X	X
Fragillaria				X
Gomphonema	X	X	X	X
Melosira	X	X	X	X
Navicula	X	X	X	X
Nitzschia	X	X	X	X

Table A.1 (continued)

Taxon	White Oak Creek			Melton Branch
	WOCK 6.3[a]	WOCK 2.7	WOCK 2.1	MBK 0.6[b]
Bacillariophyceae (cont.)				
Rhoicosphenia	X	X	X	X
Surirella		X	X	X
Synedra	X	X	X	X
Others				
Synura			X	
Cyanophyta				
Anacystis			X	X
Aphanizomenon			X	
Chroococcus			X	
Dactylococcopsis		X		X
Lyngbya	X	X	X	X
Merismopedia				X
Oscillatoria				X
Oscillatoria (spiral)	X	X	X	X
Raphidiopsis				X
Euglenophyta				
Euglena		X		X
Phacus			X	
Trachelomonas			X	
Pyrrophyta				
Gymnodinium			X	
Number of genera collected	20	27	37	32

[a] White Oak Creek kilometer 6.3.

[b] Melton Branch kilometer 0.6.

Table A.2. Benthic macroinvertebrate taxa collected at four sites in Upper White Oak Creek watershed, March 1979-February 1980

An "X" denotes presence of the taxon in at least one of the samples from that site

Taxon	White Oak Creek			Melton Branch
	WOCK 6.3[a]	WOCK 2.7	WOCK 2.1	MBK 0.6[b]
Annelida				
Oligochaeta	X	X	X	X
Arthropoda				
Crustacea				
Amphipoda				
Gammarus	X			X
Decapoda				
Cambarus	X			
Isopoda				
Asellus	X			
Lirceus	X			X
Insecta				
Coleoptera				
Dubiraphia	X			
Ectopria				X
Optioservus	X	X[c]		X
Stenelmis	X	X[c]	X	X
Collembola				
Isotoma	X[d]	X		
Diptera				X[e]
Chironomidae	X	X	X	X
Empipidae	X	X	X	X
Heleidae			X	X
Simulidae				
Simulium	X	X	X	
Tabanidae				
Chrysops ?	X			
Unidentified	X	X	X	X
Tipulidae				
Hexatoma	X			X
Pseudolimnophila	X			
Tipula	X			X
Unidentified		X		

Table A.2 (continued)

Taxon	White Oak Creek			Melton Branch
	WOCK 6.3[a]	WOCK 2.7	WOCK 2.1	MBK 0.6[b]
Arthropoda				
Insecta (cont.)				
Ephemeroptera				
Ameletus	X			X
Baetis	X			X
Caenis	X			
Centroptilum	X			X
Ephemerella	X			
Ephemera	X			
Isonychia	X			
Paraleptophlebia	X			
Pseudocloeon	X			
Stenacron	X[c]			
Stenonema	X			
Unidentified		X[f]		
Hemiptera		X		
Corixidae				
Rhagovelia	X			
Gerridae				
Trepobates		X		
Megaloptera				
Nigronia	X			X
Sialis	X			X
Odonata				
Argia				X
Agrion	X			X
Cordulegaster				X[c]
Lanthus	X			X
Plecoptera				
Acroneuria				X
Alloperla	X			
Isoperla	X			
Leuctra	X			
Nemoura	X			X
Tricoptera				
Cheumatopsyche	X	X		
Diplectrona	X[c]			
Hydroptila	X			
Molanna	X			
Neophylax	X			
Polycentropus	X			
Pycnopsyche	X			
Rhyacophila	X			

Table A.2 (continued)

Taxon	White Oak Creek			Melton Branch
	WOCK 6.3[a]	WOCK 2.7	WOCK 2.1	MBK 0.6[b]
Nematoda		X	X	X
Platyhelminthes				
Turbellaria				
Planariidae			X	
Number of taxa collected	44	14	9	25

[a]White Oak Creek kilometer 6.3.

[b]Melton Branch kilometer 0.6.

[c]One individual collected in qualitative samples only.

[d]Identified to family (Isotomidae).

[e]One individual belonging to the suborder Brachycera.

[f]One damaged individual that could only be identified to order.

Appendix B

PHYTOPLANKTON, ZOOPLANKTON, ICHTHYOPLANKTON, PERIPHYTON, AND BENTHIC MACROINVERTEBRATE TAXA COLLECTED IN WHITE OAK LAKE, WHITE OAK CREEK EMBAYMENT, AND THE CLINCH RIVER DURING THE ORNL SAMPLING PROGRAM

Table B.1. Phytoplankton taxa collected from White Oak Lake [station White Oak Creek kilometer (WOCK) 1.1], White Oak Creek embayment, and two sites in the Clinch River, March 1979-February 1980

An "X" denotes presence of the taxon in at least one of the samples from that site

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Chlorophyta				
Chlorococcales				
Actinastrum	X	X	X	X
Ankistrodesmus	X	X	X	X
Botryococcus	X	X	X	
Bracteacoccus		X		X
Chlorella	X	X	X	X
Chlorococcum	X	X		
Chodatella	X	X	X	X
Closteriopsis		X	X	X
Coelastrum	X	X	X	X
Crucigenia	X	X	X	X
Dictyosphaerium	X	X	X	X
Golenkinia	X	X	X	X
Kirchneriella	X	X	X	X
Micractinium	X	X	X	X
Myrmecia (MPG[b])	X			
Oocystis	X	X	X	X
Pediastrum	X	X	X	X
Polyedriopsis	X	X		X
Quadrigula	X	X		
Scenedesmus	X	X	X	X
Schroederia	X	X	X	X
Selenastrum	X	X	X	X
Tetraedron	X			
Tetrastrum	X	X		
Treubaria		X		X
Trochiscia	X	X	X	X
Unidentified	X			
Volvocales				
Carteria	X	X	X	X
Chlamydomonas	X	X	X	X
Chlorogonium	X	X	X	X
Eudorina	X	X		X
Gonium	X	X		X
Pandorina	X	X	X	X
Pleodorina	X	X		X
Pteromonas	X	X	X	X

Table B.1 (continued)

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Others				
Cosmarium	X	X		
Elakatothrix	X	X	X	X
Euastrum	X			
Gloeocystis	X	X		
Protococcus	X	X		
Rhizoclonium		X		
Spondylosium	X			
Staurastrum	X		X	
Stigeoclonium	X	X		
Unidentified Chlorophyta	X	X	X	X
Unidentified Colonial greens	X	X		
Chrysophyta				
Bacillariophyceae				
Achnanthes	X	X	X	X
Asterionella		X	X	X
Attheya		X	X	X
Chaetoceros		X	X	X
Cocconeis	X	X	X	X
Cyclotella	X	X	X	X
Cymbella	X	X	X	X
Diatoma	X	X	X	X
Fragillaria		X	X	X
Gomphonema	X	X		X
Gyrosigma		X	X	X
Melosira	X	X	X	X
Meridion	X			
Navicula	X	X	X	X
Nitzschia	X	X	X	X
Pinnularia	X			
Rhizosolenia		X	X	X
Rhoicosphenia			X	X
Stephanodiscus	X	X	X	X
Surirella	X	X	X	X
Synedra	X	X	X	X
Tabellaria			X	
Others				
Dinobryon	X	X	X	X
Ochromonas (MPG[b])	X	X	X	X
Synura		X		

Table B.1 (continued)

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Cryptophyta				
Cryptomonas	X	X	X	X
Cyanophyta				
Anabaena	X	X		X
Anacystis	X	X	X	X
Dactylococcopsis	X	X	X	X
Lyngbya	X			
Merismopedia	X	X	X	X
Oscillatoria				X
Oscillatoria (spiral)	X	X	X	X
Raphidiopsis				X
Euglenophyta				
Cryptoglena	X			
Euglena	X	X	X	X
Phacus	X	X		
Trachelomonas	X	X	X	X
Pyrrophyta				
Ceratium		X	X	X
Glenodinium	X	X	X	X
Gymnodinium	X	X	X	X
Peridinium				X
Number of genera collected	68	71	56	63

[a]Clinch River kilometer 35.4.

[b]Most probable genus.

Table B.2. Zooplankton taxa collected from White Oak Lake [station White Oak Creek kilometer (WOCK) 1.1], White Oak Creek embayment, and two sites on the Clinch River, March 1979-February 1980

An "X" denotes presence of the taxon in at least one of the samples from that site

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Arthropoda				
Crustacea				
Cladocera				
Alona quadrangularis				X
A. rectangula	X	X		X
Alonella sp.		X		
Bosmina longirostris	X	X	X	X
Ceriodaphnia lacustris	X	X	X	X
C. quadrangula	X	X	X	X
Chydorus sp.	X	X	X	X
Daphnia laevis	X			
D. parvula	X	X	X	X
D. retrocurva	X	X	X	X
D. rosea	X	X	X	X
Diaphanosoma leuchtenbergianum	X	X	X	X
Ilyocryptus	X			X
Leptodora kindtii	X	X	X	X
Macrothrix laticornis				X
Moina micrura	X	X	X	X
M. minuta		X		X
Pleuroxus sp.	X			
P. denticulatus	X	X	X	X
P. hamulatus			X	X
Scapholebris kingi	X	X	X	X
Sida crystallina		X	X	X
Simocephalus serrulatus	X	X		X
Copepoda				
Calanoida				
Diaptomus birgei			X	
D. pallidus	X	X	X	X
D. reighardi	X	X	X	X
D. sanguineus		X	X	X
Cyclopoida				
Cyclops bicuspidatus thomasi	X	X	X	X
C. varicans rubellus	X		X	X
C. vernalis	X	X	X	X
Ergasilus sp.				X

Table B.2 (continued)

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Cyclopoida (con't)				
Eucyclops agilis	X	X	X	X
E. speratus	X	X	X	X
Macrocyclops albidus	X	X	X	X
Mesocyclops edax	X	X	X	X
Tropocyclops prasinus	X	X	X	X
Harpacticoida				
Nitocra lacustris		X	X	
Unidentified	X	X	X	X
Rotifera				
Bdelloidea				
Rotaria sp.	X	X	X	X
R. neptunia				X
Unidentified	X	X	X	
Monogononta				
Asplanchna sp.		X		
A. amphora		X	X	X
A. herricki	X	X	X	X
A. priodonta		X	X	X
Brachionus angularis	X	X	X	X
B. bennini		X		
B. bidentata	X	X	X	X
B. budapestinensis	X	X	X	X
B. calyciflorus	X	X	X	X
B. caudatus	X	X	X	X
B. havanaensis	X	X	X	X
B. nilsoni		X		
B. quadridentatus	X	X	X	X
B. rubens	X			
B. urceolaris	X		X	X
Cephalodella sp.	X	X	X	X
Collotheca sp.	X	X	X	X
Conochiloides sp.		X	X	X
Conochilus hippocrepis				X
C. unicornis	X	X	X	X
Epiphanes macrourus	X	X	X	X
Euchlanis sp.	X	X	X	X
Filinia sp.			X	X
F. limnetica			X	X
F. longiseta	X	X	X	X
Gastropus sp.	X	X	X	X
Hexarthra sp.	X	X	X	X
H. mira				X

Table B.2 (continued)

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Monogononta (con't)				
Kellicottia bostoniensis	X	X	X	X
K. longispina		X	X	X
Keratella sp.	X	X	X	X
K. americana	X	X	X	X
K. cochlearis	X	X	X	X
K. crassa	X	X	X	X
K. earlinae	X	X	X	X
K. valga		X		
Lecane sp.	X	X	X	X
L. leontina	X	X		
Lepadella sp.	X	X	X	X
Machrochaetus subquadratus		X	X	X
Monostyla sp.	X	X	X	X
M. bulla	X	X		X
M. quadridentata	X		X	
Mytilina sp.	X	X	X	
M. ventralis	X			
Notholca sp.	X	X	X	X
Notommata	X		X	X
Platyias patulus	X	X	X	X
P. quadricornis	X	X		
Ploesoma hudsoni			X	X
P. truncata	X	X	X	X
Polyarthra sp.	X	X	X	X
Synchaeta sp.	X	X	X	X
S. stylata		X	X	X
Testudinella sp.	X		X	X
Trichocerca sp.	X	X	X	X
Trichotria sp.	X		X	X
Unidentified	X	X		
Number of taxa collected	70	74	74	80

[a]Clinch River kilometer 35.4.

Table B.3. Ichthyoplankton taxa collected during the ORNL sampling program, March 12-September 25, 1980

Station White Oak Creek kilometer (WOCK) 1.1 is located in White Oak Lake. For each of the stations, an "X" denotes presence of the taxon in at least one of the samples from that site

Taxon	White Oak Creek			Clinch River	
	WOCK 2.1	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Catostomidae					X
Centrarchidae					
Lepomis	X	X	X	X	X
Pomoxis					X
Clupeidae		X	X	X	X
Cyprinidae	X				X
Cyprinus carpio				X	X
Percichthyidae					
Morone				X	X
Sciaenidae					
Aplodinotus grunniens				X[b]	X[b]
Unidentified fish eggs			X	X	

[a]Clinch River kilometer 35.4.

[b]Both eggs and larvae collected.

Table B.4. Periphyton taxa collected from White Oak Lake [station White Oak Creek kilometer (WOCK) 1.1], White Oak Creek embayment, and two sites on the Clinch River, June 1979-March 1980

An "X" denotes presence of the taxon in at least one of the samples from that site

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Chlorophyta				
Chlorococcales				
Ankistrodesmus	X	X	X	X
Chlorella	X	X	X	
Chodatella	X			
Coelastrum	X			
Crucigenia			X	
Golenkinia	X		X	
Kirchneriella	X			X
Oocystis	X		X	X
Pediastrum	X			
Scenedesmus	X	X	X	X
Schroederia		X		
Tetraedron	X			X
Volvocales				
Chlamydomonas	X	X	X	X
Pteromonas	X		X	
Others				
Cosmarium	X			
Gloeocystis	X	X		
Mougeotia	X	X	X	X
Oedogonium	X			
Protococcus	X	X		
Spondylosium		X		
Stigeoclonium	X	X	X	X
Unidentified Chlorophyta	X	X		
Unidentified Colonial greens	X	X		
Chrysophyta				
Bacillariophyceae				
Achnanthes	X	X	X	X
Cocconeis	X	X	X	X
Cyclotella	X		X	X

Table B.4 (continued)

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Bacillariophyceae (con't)				
Cymbella	X	X	X	X
Diatoma	X	X	X	X
Fragilaria			X	X
Gomphonema	X	X	X	X
Gyrosigma		X	X	X
Melosira		X	X	X
Navicula	X	X	X	X
Nitzschia	X	X	X	X
Rhoicosphenia		X		
Stephanodiscus	X			X
Surirella	X			X
Synedra	X	X	X	X
Others				
Dinobryon	X			
Cryptophyta				
Cryptomonas			X	
Cyanophyta				
Anacystis	X	X		
Chroococcus	X	X		
Dactylococcopsis	X	X		X
Lyngbya	X	X		X
Merismopedia	X	X		
Oscillatoria (spiral)	X	X	X	X
Euglenophyta				
Euglena	X	X		X
Trachelomonas	X			
Pyrrophyta				
Gymnodinium		X		
Number of genera collected	38	29	25	26

[a]Clinch River kilometer 35.4.

Table B.5. Benthic macroinvertebrate taxa collected from White Oak Lake [station White Oak Creek kilometer (WOCK) 1.1], White Oak Creek embayment, and two sites in the Clinch River, March 1979–February 1980

An "X" denotes presence of the taxon in at least one of the samples from that site

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Annelida				
Hirudinea				X
Oligochaeta	X	X	X	X
Arthropoda				
Crustacea				
Isopoda				
Lirceus			X	
Insecta				
Coleoptera				
Dubiraphia		X		X
Diptera				
Ceratopogonidae				
Palpomyia	X	X		
Heleidae	X	X		
Chironomidae	X	X	X	X
Culicidae				
Chaoborus sp.	X	X		X
Tipulidae		X		
Ephemeroptera				
Caenis	X	X	X	
Callibaetis	X			
Hexagenia				X
Stenacron			X	
Odonata				
Coenagrionidae				
Coenagrion	X			
Ischnura	X			
Unidentified	X			
Libellulidae				
Libellula	X			
Perithemis	X			
Unidentified	X			
Trichoptera				
Hydroptila				X
Neureclipsis		X		X
Oecetis				X

Table B.5 (continued)

Taxon	White Oak Creek		Clinch River	
	WOCK 1.1	WOCK 0.2	CRK 35.4[a]	CRK 30.6
Mollusca				
Gastropoda				
Prosobranchia				
Pleuroceridae				
Anculosa			X	
Pleurocera			X	
Pulmonata				
Ancylidae				
Ferrissia				X
Physidae				
Physa	X	X		
Planorbidae		X		
Pelecypoda				
Corbiculidae				
Corbicula manilensis	X	X	X	X
Sphaeridae		X		
Nematoda		X	X	X
Number of taxa collected	13	14	9	12

[a]Clinch River kilometer 35.4.

Appendix C

CHIRONOMID SPECIES IDENTIFIED IN SELECTED BENTHIC SAMPLES COLLECTED DURING THE ORNL SAMPLING PROGRAM

Table C.1. Chironomid species identified from selected benthic macroinvertebrate samples collected during the ORNL sampling program, March 1979–February 1980

Number of samples examined is in parentheses. An "X" denotes presence of species in at least one of the samples examined

	Sampling site							
	WOCK[a]					MBK[b]	CRK[c]	
	6.3 (3)	2.7 (3)	2.1 (5)	1.1 (5)	0.2 (4)	0.6 (7)	35.4 (3)	30.6 (2)
Chironomidae								
Tanypodinae								
Clinotanypus sp.				X				
Coelotanypus tricolor				X				
Conchapelopia sp.		X	X			X		
Larsia sp. ?						X		
Procladius sp.	X			X				
Chironominae								
Tanytarsini								
Rheotanytarsus sp.					X		X	X
Tanytarsus sp. ?					X		X	X
Chironomini								
Chironomus sp.					X			
Endochironomus sp.							X	
Glyptotendipes sp.			X		X			X
Microtendipes sp.	X							
Parachironomus				X				
P. alatus ?				X				
Polypedilum sp.					X	X		
P. halterale				X				
P. illinoinse ?						X		
Orthocladiinae								
Cardiocladius	X							
Cricotopus sp.	X	X	X			X		
Unidentified	X					X		

[a]White Oak Creek kilometer.

[b]Melton Branch kilometer.

[c]Clinch River kilometer.

Appendix D

CONCENTRATION OF HEAVY METALS IN MUSCLE TISSUE OF FISHES COLLECTED FROM WHITE OAK LAKE, WHITE OAK CREEK EMBAYMENT, THE CLINCH RIVER, AND MELTON HILL RESERVOIR DURING THE ORNL SAMPLING PROGRAM

Table D.1. Concentration of heavy metals in muscle tissue of fish collected by gillnetting at stations Clinch River kilometer (CRK) 35.4 and CRK 30.6 in March 1979

Species	Total length (cm)	Weight (g)	Concentration (μg/g, wet weight)						
			Cd[a]	Cr	Cu	Hg[a]	Ni	Pb	Zn
			CRK 35.4 CRM 22						
Sauger									
1	44.5	952	1.1	0.054	0.09	76	0.34	0.014	2.2
2	31.1	238	<0.5	0.29	0.20	69	0.40	0.016	3.8
3	42.4	663	0.6	0.042	0.21	175	0.44	0.006	2.8
4	34.9	381	<0.5	0.087	0.17	100	0.45	0.017	3.0
5	39.8	606	<0.5	0.045	0.22	92	0.38	0.014	2.5
6	37.9	514	<0.5	0.017	0.23	93	0.42	0.008	2.7
7	45.2	1058	<0.5	0.019	0.20	197	0.38	0.007	2.2
8	41.3	727	0.8	0.068	0.13	65	0.25	0.016	2.0
9	26.9	150	<0.5	0.040	0.18	96	0.71	0.010	2.8
10	37.6	466	<0.5	0.016	0.18	63	1.1	0.008	2.0
			CRK 30.6 CRM 19						
Sauger									
1	31.5	245	<0.5	0.012	0.15	58	0.52	0.014	2.9
2	37.4	427	<0.5	0.014	0.16	54	1.2	0.010	3.3
3	44.0	764	0.5	0.011	0.22	129	0.59	0.016	2.8
4	37.6	517	2.4	0.007	0.13	68	0.30	0.009	2.8
Striped bass									
1	41.6	848	<0.5	0.016	0.29	85	0.34	0.003	2.5
2	29.6	222	0.5	0.025	0.28	96	3.9	0.015	3.4
3	58.2	2681	<0.5	0.009	0.15	220	0.38	0.008	3.1
Yellow bass									
1	21.8	131	1.9	0.015	0.32	148	1.4	0.008	3.6
2	20.0	100	1.5	0.025	0.46	77	1.5	0.023	3.9
3	17.8	64	0.8	0.021	0.23	76	0.95	0.051	4.8

[a]Concentration in ng/g, wet weight.

Table D.2. Concentration of heavy metals in muscle tissue of bluegill collected by electroshocking at four stations in December 1979

Sample	Total length (cm)	Weight (g)	Concentration (μg/g, wet weight)						
			Cd[a]	Cr	Cu	Hg	Ni	Pb	Zn
			CRK 35.4[b]						
1	15.2	58.5	7.3	0.035	0.27	0.059	0.49	0.062	6.6
2	14.2	59.6	7.9	0.032	0.14	0.51	0.17	0.035	5.8
3	14.7	52.9	2.0	0.016	0.15	0.042	0.19	0.078	5.0
4	14.2	46.8	11	0.063	0.29	0.064	3.9	0.079	7.1
5	15.8	83.4	4.0	0.037	0.22	1.07	0.38	0.042	6.2
6	17.3	75.8	9.4	0.044	0.18	0.103	0.32	0.052	7.2
7	17.4	86.7	3.2	0.045	0.15	0.093	0.47	0.032	6.0
8	17.7	96.7	<1	0.028	0.37	0.037	1.8	0.021	5.1
9	19.2	100.3	33	0.040	0.08	0.092	0.49	0.023	7.0
10	18.5	111.6	<1	0.040	0.09	0.047	0.61	0.020	5.7
			CRK 30.6						
1	14.7	56.0	<1	0.048	1.16	0.030	0.58	0.030	8.0
2	15.0	53.9	8.9	0.093	0.36	0.030	0.52	0.042	7.1
3	14.8	55.6	<1	0.050	0.38	0.059	0.39	0.038	6.3
4	15.8	63.7	10	0.050	0.39	0.051	0.60	0.055	5.4
5	17.0	86.1	4.2	0.055	0.23	0.094	0.37	0.021	6.9
6	17.9	109.5	<1	0.035	0.12	0.115	0.49	0.29	4.1
7	17.0	87.3	31	0.064	0.12	0.050	2.0	0.037	3.6
8	19.6	119.5	<1	0.011	0.10	0.080	0.39	0.034	4.9
9	17.9	113.3	23	0.14	0.13	0.065	0.44	0.031	4.0
10	17.5	111.4	47	0.016	0.15	0.066	0.18	0.029	3.4
			CRK 84 (Melton Hill Reservoir)						
1	15.8	68.7	41	0.022	0.06	0.072	0.23	0.038	6.0
2	14.9	65.3	26	0.033	0.08	0.077	0.23	0.025	4.9
3	15.2	63.1	20	0.042	0.12	0.057	0.65	0.020	6.0
4	16.0	64.2	1.1	0.024	0.15	0.050	0.62	0.017	7.5
5	16.2	83.7	12	0.026	0.24	0.063	0.23	0.022	5.1
6	17.3	103.9	3.3	0.030	0.17	0.031	0.32	0.019	4.5
7	17.4	95.8	27	0.029	0.08	0.057	0.31	0.022	4.7
8	17.8	110.5	1.4	0.026	0.13	0.051	0.25	0.034	5.5
9	18.0	113.4	42	0.044	0.22	0.074	0.50	0.042	4.5
10	19.4	128.0	4.0	0.028	0.30	0.073	0.67	0.034	5.0
			WOCK 0.2[c]						
1	14.4	36.6	<1	0.064	0.82	0.69	0.08	0.017	1.9
2	14.4	61.2	<1	0.035	0.09	0.70	0.04	0.052	6.6
3	14.0	51.8	1.4	0.042	0.21	0.47	0.68	0.038	7.9
4	15.3	42.5	6.4	0.026	0.12	0.42	0.08	0.054	6.9

[a]Concentration in ng/g, wet weight.

[b]Clinch River kilometer 35.4.

[c]White Oak Creek kilometer 0.2.

Table D.3. Concentration of heavy metals in muscle tissue of fish collected by electroshocking in White Oak Lake during the summer of 1979

Species	Total length (cm)	Weight (g)	Concentration (µg/g, wet weight)						
			Cd[a]	Cr	Cu	Hg	Ni	Pb	Zn
			June 20						
Largemouth bass									
1	28.8	281.0	13	0.021	0.16	0.94	0.23	0.013	6.1
2	25.7	204.2	<1	0.024	0.23	0.92	0.25	0.013	6.1
3	11.8	20.9	4.0	0.015	0.24	0.27	3.5	0.18	7.8
			July 2						
1	16.4	52.7	<1	0.040	0.22	0.49	1.5	0.029	7.3
2	26.6	236.1	<1	0.034	0.30	0.36	0.39	0.039	3.9
			August 30						
Bluegill									
1	14.3	67.6	16	0.017	0.18	0.51	1.6	0.066	6.0
2	14.9	74.7	3.9	0.023	0.11	1.02	0.41	0.013	5.9
3	14.5	69.1	1.2	0.033	0.16	0.79	0.44	0.025	6.0
4	15.4	73.6	8.9	0.036	0.16	0.89	0.68	0.020	5.9
5	16.2	81.6	2.7	0.044	0.14	0.52	0.18	0.057	5.8
6	16.0	92.3	2.2	0.025	0.15	1.05	0.39	0.075	7.2
7	16.1	93.5	<1	0.025	0.17	0.68	0.15	0.044	6.0
8	16.0	94.7	1.5	0.022	0.22	0.58	0.44	0.032	6.1
9	16.8	103.1	12	0.036	0.17	0.49	0.29	0.032	5.7
10	16.9	111.4	2.9	0.010	0.13	0.51	0.05	0.028	4.6

[a]Concentration in ng/g, wet weight.

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